Gas Journal

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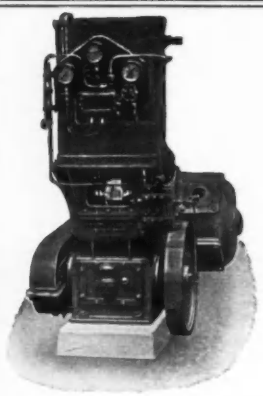

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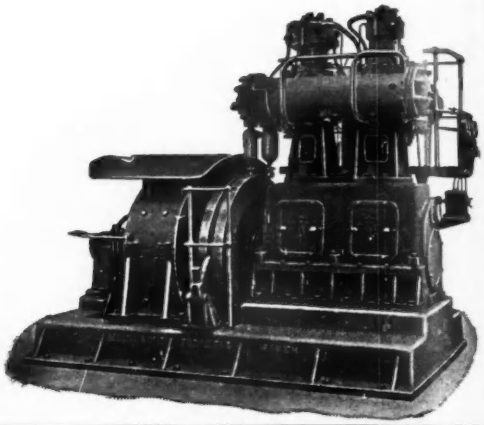

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Gas Journal

VOL. 298 *No. 4996* *APRIL 15, 1959*

IIITH YEAR

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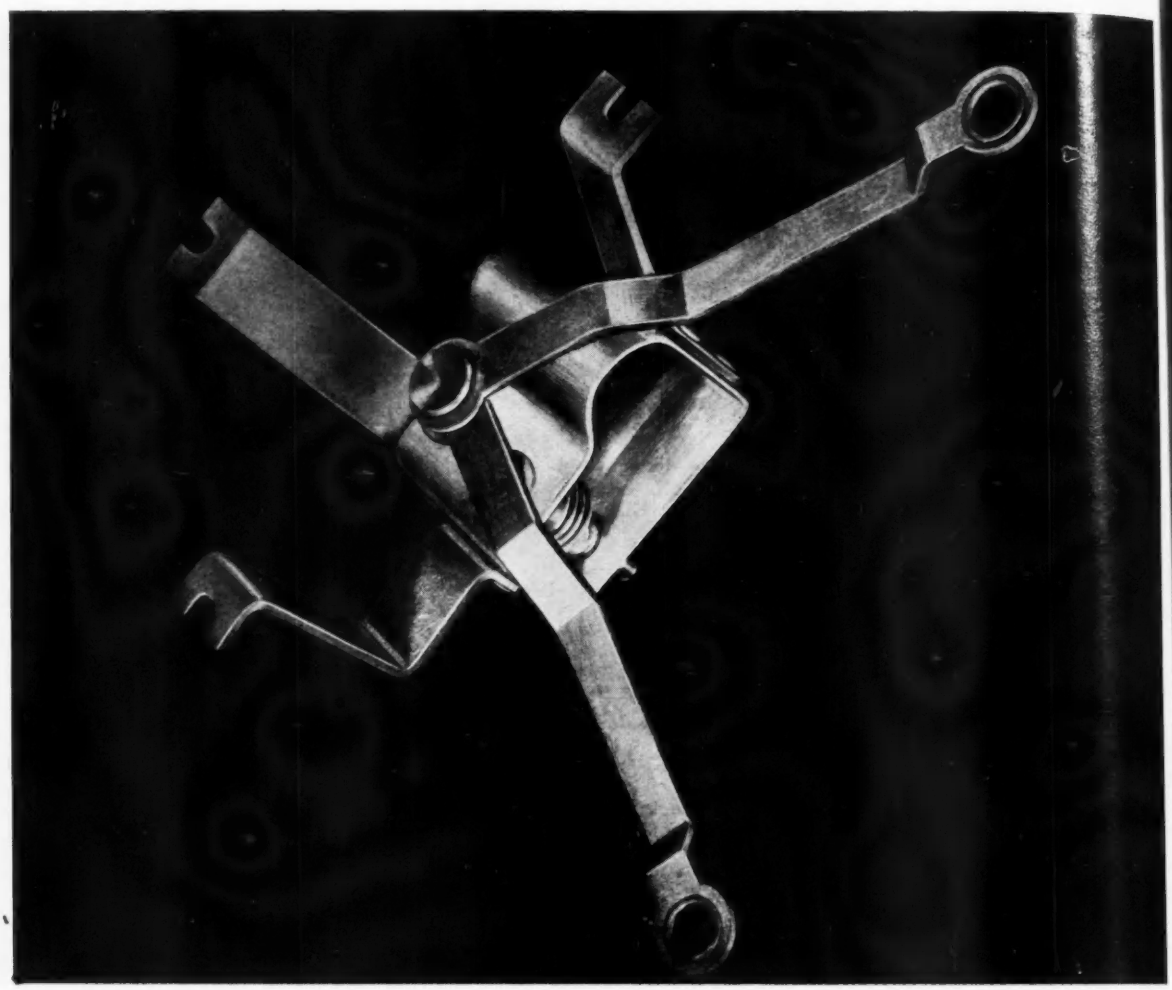

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1959

Gas Journal

VOLUME 298. No. 4996 APRIL 15, 1959. 111th YEAR

The Industry and Oil

THE gas industry continues to take an ever increasing interest in oil or its products as a raw material for gas making. So great is this interest becoming that we are devoting the greater part of our current issue to this use of oil by the industry.

Why should an industry traditionally linked to coal, so suddenly turn its attention to oil, an imported fuel? Although it is only since the Second World War that oil has been used in its own right for gas making in Britain, the carburetting of blue water gas on a commercial scale in this country dates from the end of the last century. In America, the need for peak load gas of a calorific value equal to natural gas favoured the development of 'high B.t.u.' gas from oil.

In Great Britain since the war the shortage of suitable coals for carbonising, their cost and the ever-rising freight rates, forced the gas industry to look for an alternate basic raw material for gas making. The building of refineries here after the war by oil companies with international connections brought the oil to the industry's doorstep. Since the demand for certain types of oil products might vary, those products in low demand could become the feed-stocks of the gas industry, and the oil industry could dispose of them at competitive prices. Here then seemed to be the solution to the coal shortage and here also a means by which the price of gas might remain more competitive with other fuels.

The capital cost of the oil plants was lower, and being much more flexible, they could be more easily and economically used in times of varying demand. Oil, being a liquid, lent itself to modern methods of handling and could be gasified in automatic plants, which took up a much smaller ground area than a carbonising plant of equal gas-making capacity.

With increasing imports of oil into this country designed to overcome coal shortages in other branches of industry, the use of oil for central heating began to spread, and with it the danger of it superceding gas coke in commercial and industrial central heating boilers. The case then for the use of oil for gas making was strengthened. The availability of gas of high calorific value from the refineries was another factor causing the gas industry to loosen its traditional link with the coal industry.

In our issue this week we have attempted to cover the main points of interest to the gas engineer in adopting oil to gas making. A paper by Mr. W. J. Cutler, of the Power-Gas Corporation Ltd., describes many of the oil gasification processes now in use in this country, on the continent of Europe and in America. This most interesting review gives an idea how much work has been done on the subject. Mr. A. K. Davis, of the Shell Petroleum Co., Ltd., deals with production of refinery gas, and refers to the new reforming plant of the North Thames Gas Board at Romford, a plant with a potential capacity of 36 mill. cu.ft. per day of town gas from refinery gas. As our main feature, however, we are publishing an account of the South Eastern Gas Board's new oil gasification plant at the Isle of Grain, on the south bank of the Thames Estuary. This works, the largest oil gasification plant yet to be built in Great Britain, represents the completion of the first phase in a gas-making project with a possible potential output of 80 mill. cu.ft. per day. The plant we describe, a Segas plant with a potential output of 20 mill. cu.ft. per day of a gas of 500 B.t.u. per cu. ft., was commissioned late last year, and in the intervening months has shown itself remarkably trouble-free, thus vindicating the decision of the Board to install a plant of this type and size.

The plant, the second phase of which is now under construction, is complementary to the first, and takes the form of a Shell/W.-D. plant of similar capacity, making a gas rich in hydrogen but low in carbon monoxide and sulphur. The gas will, therefore, be of low

specific gravity, low toxicity, and lower calorific value. If this constituent gas is mixed with a gas of high calorific value from the Segas plant, a town gas of controlled combustion characteristics without the most obvious disadvantages of a conventional coal gas becomes a possibility. Added to this, the cost of gas production at Grain, situated as the plant is on an adjacent site to the Kent Oil Refinery of British Petroleum Ltd., is competitive with gas at other large London gasworks, and does not depend on the prices that can be realised for coke and other by-products. This latter point is, we think, of the greatest importance, since if the competitive price of town gas depends largely on the sale of coke, and this in turn is made more difficult by the spread of oil-fired central heating, any large increases in gas demand, even the capture of the central heating load by gas itself, can be far more easily met if unaccompanied by increased tonnages of coke for disposal.

The plant at the Isle of Grain undoubtedly represents something more than a change of raw material. It is highly instrumented and controlled from a centralised control room, more on the lines of an oil refinery than even the most up-to-date gasworks. This has meant that the type of man recruited to operate it is more highly trained and imbued with quite a different outlook on gas making than his counterpart at a conventional carbonising plant.

When the materials to be transmitted are fluids, the remote control of the plant and the possibility of being able to work to predetermined settings becomes a reality, and this we think is the shape of things to come. The completed project at Grain may well represent the type of the industry's production stations of the future.

For such a project to be possible, certain conditions must be satisfied. The plant must be perfectly flexible in being able to gasify any available feedstock. This the Grain plant seems able to do, but the processes described by Mr. Cutler are particularly interesting in that they give a choice from which the gas engineer may decide the most suitable plant for his purpose. Another condition to be satisfied is the proximity of the source of feedstock, which in turn involves a mutual understanding of the problems of both oil company and gas board.

This we think is of greatest importance, since at the Isle of Grain the South Eastern Board depends on British Petroleum Ltd. not only for the preliminary training of its plant operators, but also for the integration of the gasification plant in the refinery's planned maintenance scheme. We hope such dependence is only temporary until the Board has completed its project and is in a position to organise itself to train both plant operators and maintenance personnel to the standards demanded. At present perhaps the demand for such highly trained personnel may not be great enough to warrant a separate training scheme, but should the industry need numbers of operators of this type in the future, their training should not, we feel, be dependent on the good offices of another industry.

Halcyon Days

IN a recent issue we commented on the potential importance to the industry of warm air heating and suggested that a vigorous promotion of this type of service, allied to really competitive tariffs, would provide the type of stable load gas needs. In view of the sentiments we had expressed it was with more than average interest that we attended one of two functions held last week by the South Eastern Gas Board to celebrate their success in selling Sugg Halcyon heaters; in fact in the Board's area well over a thousand Halcyon systems have been installed and orders total nearly 1,900. That number will no doubt be substantially increased as a result of the distinguished company of architects and housing officers who visited the Savoy Hotel to see the Board's excellent display and hear Mr. W. K. Hutchison give a pithy talk on the attractions of warmed air, supported (technically) by Mr. G. H. Fuidge, Manager of the Board's Central Laboratories, and (morally) by Mr. Norman Wates, of Wates, Ltd., the builders who have given their support to this appliance.

Mr. Hutchison said that three years ago the Board had set out on a battle to recover the space heating load and they had made a three-pronged attack. First, they had devised a two-part tariff under which gas could be supplied at a competitive price. Secondly, they had reviewed production techniques to make sure that any demands for gas could be met. And thirdly, they had looked around for the right appliances. 'I think this is a complete breakthrough on the home heating front,' he concluded. 'We are going to fan out from there to conquer all enemy positions.'

The impressive display arranged by the Board and the very attractive publicity material it has produced, coupled with an obvious determination to widen the field of Halcyon sales in both local authority and private building schemes, seem likely to ensure a major victory for Mr. Hutchison and his colleagues.

Capital Investment

CAPITAL expenditure by the coal, gas and electricity industries will be £70 mill. higher this year than in 1958, according to a White Paper issued last week. The combined total of approved expenditure for the three industries of £525 mill. during 1959 compares with last year's estimated £454½ mill. expenditure—£15 mill. more than the figure approved; rather less than half will be spent by the coal, gas and electricity industries with the Gas Council and Boards taking only a very small part of the increase. The section of the White Paper dealing with the Gas Council and Boards reads as follows: 'In 1958/59 the expenditure by the Gas Council and area boards on fixed assets is estimated to have been £48.8 mill. against the approved programme of £54 mill., including £0.5 mill. for the short-term works. This underspending was due to the revision of a number of projects including some dependent on the plans of other industries. The programme approved by the Minister for 1959/60 totals £55.5 mill.'

The details of the approved programme are £21.1 mill. for gas manufacture, £31.4 mill. for distribution and consumer service, and £3.0 mill. for other purposes. The White Paper makes brief reference to recent developments in the industry and concludes: 'In 1958/59 the Council's accrued liability to the Minister in respect of advances increased by £23 mill., advances in the year being £25 mill. and repayments £2 mill. The increase in 1959/60 is expected to be about £28 mill. with advances at £31 mill. and repayments £3 mill.'

Personal notes

MR. V. W. STANTON, Commercial Manager of the South Eastern Gas Board, has been appointed a member of the Board. Mr. Stanton, who is 51 years of age, will combine his new duties with those of his present appointment. He joined the South Metropolitan Gas Company in 1923. In 1932 he went to the South Suburban Gas Company and became Commercial Manager in 1940. On the formation of the South Eastern Gas Board he was appointed Commercial Manager. Mr. Stanton also succeeds MR. S. G. ABERDEIN as Chairman of the Gas Council's Commercial Managers' Committee.

MR. W. COLE, Manager and Secretary of the Castletown Gas Light Co., Ltd., has now been appointed a director of the Peel Gas Co., Ltd., Isle of Man. Mr. Cole was trained at the Royston (Yorks) & District Gas Co., Ltd., and was later transferred to Brodsworth when an amalgamation took place and this works was eventually taken over by the United Kingdom Gas Corporation.

MR. D. L. WALKER, C.B.E., General Secretary of the Federation of British Industries, has retired after 42 years in the Federation's service. He has been elected a Vice-president and has agreed to accept the appointment of Honorary Adviser to the Federation.

MR. T. H. HALSTEAD has been appointed Manager of the London branch office of Honeywell Controls Ltd., responsible for sales in the London area and the southern part of England. MR. D. RICHARDS, until recently manager of the Birmingham office, succeeds Mr. Halstead as Sales Manager of the Heating Controls Division. MR. W. R. OWEN, an instrumentation expert, takes over the Birmingham office. MR. G. FOX becomes Manager of the Leeds office.

MR. K. L. COOMBS has been appointed Divisional Manager of Webb Conveyors & Automation Ltd., one of the companies in the Elliott-Automation Group. Before joining the Elliott-Automation Group, Mr. Coombs was with Paterson Hughes Engineering Co. Ltd. and the New Conveyor Co. Ltd. and spent some considerable time when with Standard Telephone & Cables Ltd. in charge of the design and development of plant for the process industries.

MR. D. F. HAYDON, chief technical sales representative of Baird & Tatlock (London) Ltd., and Hopkin & Williams Ltd., is making a six-week tour of the Middle East. He is visiting agents, representatives and customers in the Persian Gulf, Iraq, Iran and the Lebanon.

MR. J. HUNTER-RIOCH, M.B.E., of Cambridge, has been appointed Deputy Chairman of the Cambridge and District Trustee Savings Bank in succession to the late Mr. C. C. Mason, C.B.E., who will be remembered by many in the gas industry as the former managing director of the Cambridge Instrument Company. A Trustee and Manager since 1946, Mr. Hunter-Rioch has taken a keen interest in the extension of the activities of the Bank, and was a member of the sub-committee which presented a report on development in 1947. Since that date branches have been opened in Hitchin, Letchworth, Newmarket, Biggleswade, Haverhill, Saffron Walden and Mill Road, Cambridge. The total funds of the Bank increased from £1 mill. in 1946 to over £6 mill. today, and depositors from 7,691 to 46,428.

Diary of forthcoming events

April 15.—YORKSHIRE JUNIORS: Visit to works of the Power-Gas Corporation Ltd.

April 15. — COMBUSTION ENGINEERING ASSOCIATION, NORTHERN REGION: Royal Station Hotel, Newcastle. 'Furnaces as a Source of Fuel Economy,' by A. L. Hancox, and 'The Economics of Thermal Insulation,' by J. C. Stainton. 10.30 a.m.

April 16.—INSTITUTE OF FUEL, EAST MIDLAND SECTION: Gas Showrooms, Lecture Theatre, Nottingham. Annual general meeting. 6.15 p.m.

April 17.—WALES G.C.C.: Bute Terrace, Cardiff. Council Meeting at 11 a.m.

April 20.—EASTERN G.C.C.: Connaught Rooms, Great Queen Sreet, Kingsway, W.C.2. Council meeting at 2 p.m.

April 21. — LONDON AND SOUTHERN JUNIORS: Visit to the Engineering, Marine, Welding and Nuclear Energy Exhibition.

April 21.—LONDON AND SOUTHERN SECTION, I.G.E.: Pepys House, 14, Rochester Row, Westminster, S.W.1. Paper by A. E. Haffner, Chief Engineer, Southern Gas Board.

April 22.—INSTITUTE OF FUEL: Great George Street, London, S.W.1. Presidential Address by T. C. Bailey. 6 p.m.

April 23. — LONDON AND SOUTHERN JUNIORS: Address by W. E. Dobson, of the West Midlands Gas Board, on his recent visit to the U.S.A. under the I.G.E., Woodall-Duckham Scholarship Award.

April 23.—NORTH OF ENGLAND SECTION, I.G.E.: Three Tuns Hotel, Durham. Joint Meeting with the Northern Section of the Coke Oven Managers' Association. Paper on 'Combined Operations in the East Coast Grid,' by N. Henderson. 7 p.m.

April 23.—WALES AND MONMOUTHSHIRE JUNIORS, NORTH AND SOUTH WALES SECTIONS: Newtown, Mon. Annual general meeting.

April 23.—EASTERN JUNIORS: Leicestershire. Visit to pits of East Midlands Division of the National Coal Board.

April 23.—INSTITUTE OF FUEL: Great George Street, London, S.W.1. Annual general meeting and luncheon.

April 25.—WESTERN JUNIORS: Old Bond Street, Bath. Annual general meeting. 2.30 p.m.

April 25.—MANCHESTER JUNIORS: Visit to White Lund Works, Lancaster. Paper on 'Commissioning of Intermittent Vertical Chamber Ovens,' by F. S. Gray.

April 28.—COMBUSTION ENGINEERING ASSOCIATION, WESTERN REGION: The Seabank Hotel, Porthcawl. Brains Trust on 'The Working of the Clean Air Act.' 10.30 a.m. Paper on 'Structural Insulation,' by P. E. Millington. 2.15 p.m.

April 28. — LONDON AND SOUTHERN JUNIORS: Afternoon visit to Bracknell New Town.

Correspondence

SMOG GENERATION AND FISCAL POLICY

DEAR SIR,

It is difficult to take a completely unbiased view of any Budget proposals, and we in the gas industry are unlikely to feel enthusiastic about a reduction of 3% in the price of a gas-fire, especially as it applies equally to heaters using electricity and oil, while smog-generators are still tax-free. We believe that gas provides the best solution to the space-heating problem, yet as modern gas fires are inherently more complicated than their electric counterparts, a uniform rate of tax bears more heavily upon the former.

The Shinwell winter demonstrated clearly that electric fires have a tremendous effect upon the peak load of power stations, and as nuclear power is in its infancy, anything that may make it possible to slow down on power station construction is surely in the national interest. Even when nuclear power stations are commonplace, their high capital cost will make a good load-factor desirable. Finally, it should be remembered that electricity is not made entirely from low-grade coal that the N.C.B. cannot get rid of—quite a lot is made from imported high-sulphur oil.

Hence it seems to me that the logical basis of tax for space-heaters would be, not a pro rota tax, but a flat rate of, say, £1 each. This would, incidentally, discourage the production of shoddily-made electric fires, which are a public danger.

While on the subject of fiscal policy, I should like to mention another matter that affects the gas industry—the high rate of tax or duty on so-called mechanical gas-lighters. I understand that the Ever-Ready gas lighter, for example, costs 8s. 6d. without battery or element. Of this 4s. is duty. Why this penal rate of tax? Surely not to safeguard the sales of matches, which are either imported, or made from imported timber!

THERMION.

London.
April 9, 1959.

Glover & Main takeover bid for Meters Ltd.

'Evolution of commercial development'

GLOVER & MAIN have made an offer for the whole of the preference and ordinary stock of Meters Ltd. This offer has been discussed in detail with the directors of Meters Ltd., all of whom support the proposals and have agreed to accept the offer in respect of their own shareholdings. Both companies feel that a combination such as is envisaged conforms with the evolution of commercial development today and will assist in maintaining the services for the gas industry of two active and progressive meter manufacturing concerns.

The executive directors of Meters Ltd. will be continuing in office and some discussion has already taken place on future organisation and the most desirable lines of development through concentration of effort.

Other changes

In connection with the proposals for the acquisition of the whole of the issued share capital of Meters Ltd., the directors of Glover & Main Ltd. wish to be at liberty to issue further preference shares. For this purpose it has been thought advisable to make other changes with a view to bringing the rights attached to the preference shares into conformity with modern practice. The proposals to be put to a meeting of preference shareholders are as follows:

(a) To change the annual rate of dividend from 6½% to 6% as from January 1, 1959;

(b) To provide, within defined limits, that further preference shares may be issued ranking *pari passu* with the existing preference shares;

(c) To limit the right of preference shareholders to attend and vote at general meetings.

To compensate preference shareholders for the variation of their rights it is proposed that they should receive one new fully paid preference share of £1 ranking for dividend as from January 1, 1959, for every five preference shares of £1 each at present held by them. The effective annual rate of dividend will thus be raised from the present rate of £6 10s. 0d.% (less income tax) to £7 4s. 0d.% (less income tax).

The Board of Glover & Main Ltd. also feel that this would be an opportune moment at which to bring the issued capital of the company more closely into line with the actual capital, as represented by net assets, now employed in the business.

Subject to the passing of the necessary resolution it is therefore intended to capitalise the sum of £601,407, part of the total amount now standing to the credit of capital reserves and of revenue reserves and to allot 1,202,814 new ordinary shares of 10s. each credited as fully paid to the holders of ordinary shares registered in the books of the company at the close of business on May 6, 1959, in the proportion of one new ordinary share of 10s., fully paid, for every two ordinary shares of 10s. each then held. Such new shares will entitle holders to all dividends declared payable after June 3, 1959, and will rank *pari passu* in all other respects with the existing ordinary shares of 10s. each.

The whole of the issued share capital of Meters Ltd. consists of £150,000 5½% cumulative preference stock and £350,000 ordinary stock. The consideration offered will be one fully-paid 6% cumulative preference share of £1 of Glover & Main Ltd. for each 5½% cumulative preference stock unit of £1 of Meters Ltd., and 21s. 3d. in cash for each ordinary stock unit of £1 of Meters Ltd.

The offer is conditional, *inter alia*, upon acceptance in respect of not less than 90% of the issued share capital of Meters Ltd., or such lesser percentage as Glover & Main Ltd. may agree.

A summary of the net tangible assets of Glover & Main Ltd. and its subsidiaries and of Meters Ltd., and its subsidiaries, based on the consolidated balance sheets as at December 31, 1957, and at March 31, 1958, respectively, is set out in the table.

On the assumption that the offer to the preference stockholders of Meters Ltd., becomes unconditional and the necessary resolutions are passed, the issued share capital of Glover & Main Ltd. will be 210,000 6% cumulative preference shares of £1 each and 3,608,442 ordinary shares of 10s. each.

	Glover & Main, Ltd.		Meters Ltd.	
	£	£	£	£
Fixed assets		1,493,233		272,031
Trade and sundry investments		145,958		119,239
Net current assets		2,373,729		289,973
		4,012,920		681,243
Less: Minority interests	57,785		4,417	
Future income tax	129,839		18,240	
		187,624		22,657
		£3,825,296		£658,586

GAS FROM OIL

THE Chemical Engineering Division of W. C. Holmes & Co., Ltd., has recently received an order from the South Eastern Gas Board for a 16 mill. cu.ft. per day benzole recovery and desulphurising plant. This plant is to be installed at the Isle of Grain works.

A full description of progress at the Isle of Grain is featured on p. 107, and other articles in this special issue of the 'GAS JOURNAL' also deal with 'gas from oil.'

AUSTRALIA ORDERS POWER-GAS PLANT

THE POWER-GAS CORPORATION (AUSTRALASIA) PTY., LTD., Australian subsidiary of the Power-Gas Corporation, Ltd., Stockton-on-Tees, has received an order for one unit of carburetted water gas plant from the Australian Gas Light Company for their Mortlake Works, Sydney.

Largest unit?

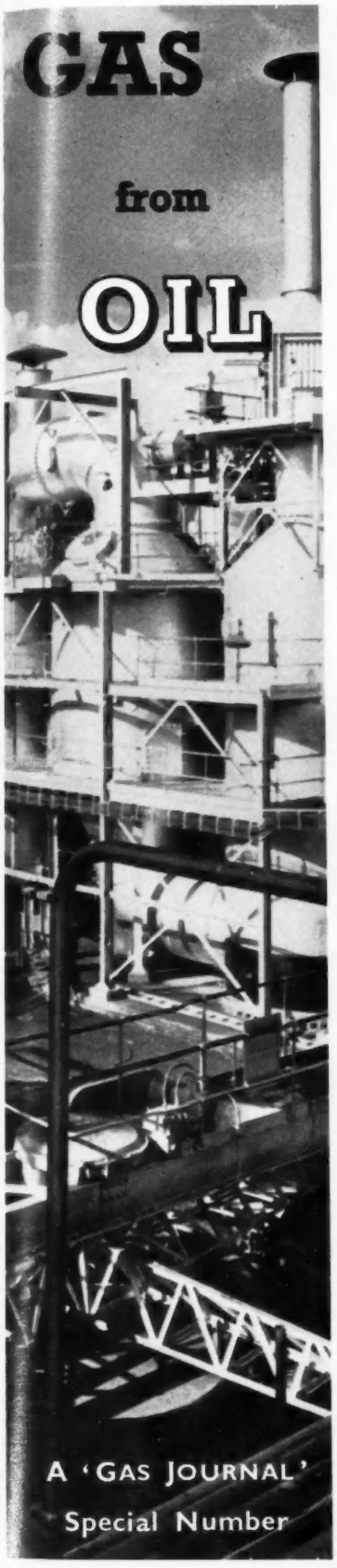
The unit will have a normal capacity of 9 mill. cu.ft. of 550 B.t.u. gas per day, with a peak load capacity of 12 mill. cu.ft. per day. It is believed to be the largest single unit of c.w.g. plant in the world.

The unit will incorporate a generator of the dry base type and will utilise the reverse flow carburetting system, for the use of heavy oil. A unique feature of the plant is that, except for certain control equipment, it will not be housed, thus following a similar trend adopted in recent years for catalytic oil gas plants. Many novel features are included in the mechanisation and instrumentation of this plant with a view to keeping labour requirements to a minimum. The contract includes all the civil engineering work and a column-guided gasholder. The site is to be laid out for future extensions and the plant itself is planned for completion by about mid-1960.

Value of the order is more than £A800,000. The manufacture of the special equipment and the engineering will be carried out at Stockton-on-Tees. Auxiliary equipment will also be supplied from this country.

Twenty installations

The Power-Gas Corporation Ltd., through their Australian subsidiary, has engineered and installed over 20 units of carburetted water gas plant in Australia, in addition, high B.t.u. oil gas plant with a capacity of 13 mill. cu.ft. per day, producer gas plant and general gasworks plant have been installed at various gasworks throughout the country.



ISLE OF GRAIN OIL GASIFICATION PROJECT

A new concept of manufacture

Illustrations by Stephen Tennant, A.R.P.S., 'GAS JOURNAL' staff photographer.

THE South Eastern Gas Board's oil gasification project at the Isle of Grain represents a new conception in gas manufacture and may well be looked upon as the first concrete example of a new era opening up for the gas industry.

The ideas behind this very far reaching project show the direction towards which the supply of refined fuels, especially oil, is moving and how, if gas is to hold its place, it too must be in a position to offer a competitive, if not a better fuel at a reduced price.

The cost of gas production should be independent of the prices realisable for coke and other by-products of coal carbonisation, and the gas-making plant must be extremely flexible both in its feedstock and in being able to supply gas cheaply in spite of wide variations in demand.

The closing down of sections of the plant at short notice without damage to it and its speedy starting up in times of very cold weather do seem possible with oil gasification plants generally. Added to this the idea of a 'tailor made,' non-toxic, gas to constant combustion characteristics should be the aim of all gas engineers. This would be both difficult and costly with carbonisation plant because of its comparative inflexibility, the varying types of coal used, and the treatment of the gas in ancillary plant to absorb or convert the carbon monoxide and carbon dioxide present.

So far only the first phase at the Isle of Grain is complete and consists of a Segas oil gasification plant, but work is going forward in the construction of the second phase. This consists of a Shell/W.-D. oil gasification plant which will produce a gas very high in hydrogen, but very low in carbon monoxide.

When complete the two plants will be worked together. Of the two twin Segas plants now working, one will have its catalyst taken out to give a gas of high calorific value, while the other will continue to make gas of a C.V. of 500 B.t.u. per cu.ft. as at present. The thermal output of the Segas section of the plant will be considerably increased.

The high hydrogen gas from the Shell/W.-D. plant, of lower calorific value, mixing with the Segas gas will reduce the overall carbon monoxide content considerably and lower the specific gravity. The resultant gas should be almost free of organic sulphur. It is clear that the town gas then entering the trunk mains at the Isle of Grain will represent the type of gas which consumers, both domestic and otherwise, are going to find eminently satisfactory.

Industry in particular should have no cause to complain of a town gas of this specification since, with its constant combustion characteristic and negligible sulphur content, it is equal to and perhaps better than other competitive fuels, whether they are liquid or gaseous, or electricity. Its low carbon monoxide content and therefore its low toxicity should have a good effect on the morale of the general public.

The shortage of gas-making coals in 1955 caused the South Eastern Gas Board to consider what evasive action should be taken to ensure gas supplies.

Coal to the Board was a mixture of foreign coals from America and the French coalfields as well as the normal Durham coals. The situation was most unsatisfactory especially since the policy to increase imports of oil might well disturb the industrial coke market which accounted for about 80% of the coke demand.

Oil was entering the country at the rate of 80 mill. tons a year and the new B.P. refinery, with a potential capacity of 9 mill. tons, had been lately completed at the Isle of Grain.

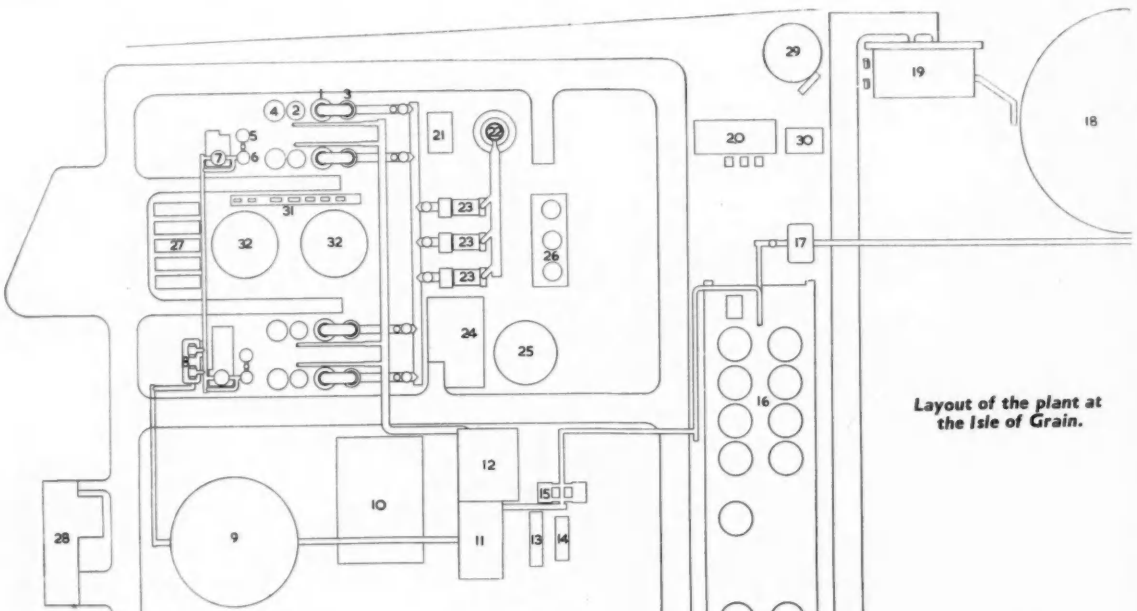
The use of oil as a raw material for gas making on a large scale

appeared to the Board to be a solution to their problems. The oil was on the spot and the refinery was willing to sell those grades for which there might not be an adequate demand at the time. Its use for gas making would form an additional basis for a price structure for costing. The only oil gasification process of which the Board had any experience was its own Segas process, which had certain limitations. Though flexible in its demands for feed stocks, the gas from heavy oil had a high proportion of organic sulphur, about 40 grains per 100 cu.ft. The high carbon dioxide content brought the specific gravity up to .55 and the high carbon monoxide content at 14% to 15% made the gas highly toxic. The decision to divide the project up into phases had considerable merits, since it would at least give the Board breathing space to investigate other gas-making processes by which a gas without the disadvantages of the Segas process might be produced, and yet allowing experience to be obtained with large-scale oil gasification. It would also make certain that additional supplies of gas were available without having to rely on imported foreign coal. The first phase then was to construct a Segas oil gasification plant with a potential capacity of 20 mill. cu.ft. per day, of gas at a C.V. of 500 B.t.u. per cu.ft. The plant was divided up in four units, working in two pairs. Each unit would have a capacity of 5 mill. cu.ft. per day using light distillate as the feed stock or 4 mill. cu.ft. per day using heavy oil.

Experiments at the Segas plant at Sydenham had shown that a high calorific value gas of 1,100 to 1,200 B.t.u. per cu.ft. could be made if the catalyst was dispensed with. The potential throughput of the plant was also very much increased. The second phase of the Isle of Grain project, it was decided, should consist of a plant the gas from which, when mixed with the gas from phase one, would correct its disadvantages to produce the 'tailor made' gas considered desirable. Several types of process were considered and the Shell/W.-D. process for the partial combustion of oil to form a gas rich in hydrogen was chosen.

The site on which plant has been built needed a very great deal of preparation before it was possible for construction work to begin. A survey showed it to be roughly 7 ft. above the National Datum, containing an area of fleets or deep ditches. It was decided to raise this to 10 ft. above N.D., level with the road to avoid the high water level of the Thames Estuary at Spring tides at 9.7 ft. above N.D. The present plant occupies about a quarter of the available site, and this section alone needed 64,000 cu. yards of raise and fill. The availability of waste matter from cement factories proved useful for back fill. A soil survey of the site revealed clay deposits at 23 ft. below ground level followed by 6 ft. of gravel underlain by stiff blue clay to a substantial depth. Since the strata above the gravel would not take a loading greater than .1 ton per sq. ft. and the variable thickness of the gravel did not permit piles to be founded there, a pile length of 50 ft. was decided upon. This length should allow a penetration of 20 ft. into the underlying clay strata. The Franki piling system was adopted and the design load of the piles driven was 45 tons. Test loading of 140 tons gave a permanent settlement of .26 in. in a total settlement of .44 in.

The oil gasification plant consists of four sets of three vessel Segas units, each capable of making 4 mill. cu ft per day of gas of 500 B.t.u. per cu.ft.



Layout of the plant at the Isle of Grain.

1. Reactor.
2. Air preheater.
3. Superheater.
4. Washbox.
5. Lymn washer.
6. Carbon washer.
7. Detarrer.
8. Plant meters.
9. Relief holder.
10. Control room and laboratory.
11. Plant boosters.
12. Blower room.
13. Steam accumulator.
14. Wash oil and creosote tank.
15. Naphthalene washers.
16. Tower purifiers.
17. Station meter.
18. Main holder.
19. Transmission boosters.
20. Main switch room.
21. Switch room.
22. Chimney.
23. Waste heat boilers.
24. Water treatment plant.
25. Raw and soft water storage tank.
26. Cooling tower.
27. Tar and oil storage tanks and pump house.
28. Offices.
29. Effluent pit.
30. Test room.
31. Tar and liquor pumps.
32. Settling pits.

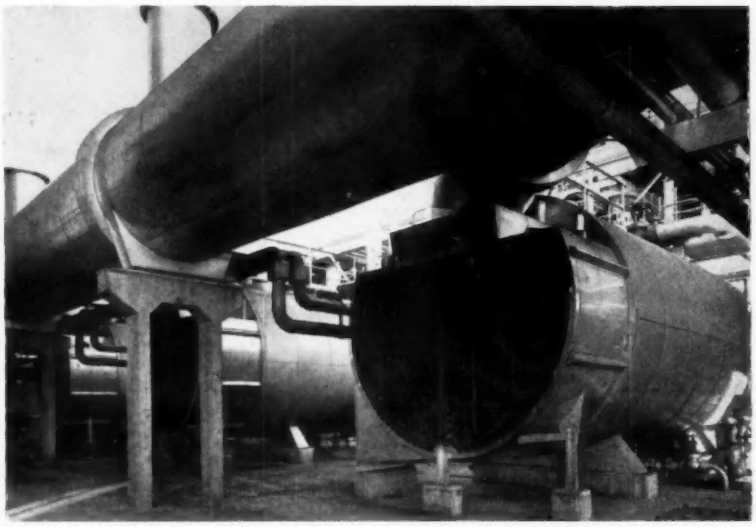
Inside the control room. The main instrument panel occupying the whole of one wall can be seen, together with the electronic calculating equipment on the extreme right. The operator can be seen at the central desk noting down important readings.

from heavy fuel oil and 5 mill. cu.ft. per day from light distillate. This type of plant will gasify anything available from a light distillate of specific gravity of .68 to an oil of 1,000 seconds viscosity. The complete plant may be worked in two pairs with the 'blow' and 'make' periods synchronised to give as far as possible a continuous make of gas.

Civil engineering work, which was carried out under the direction of the Central Construction Department of the South Eastern Gas Board by Sir Robert McAlpine & Son Ltd., began in February, 1956. By April, 1957, the Power-Gas Corporation Ltd., who are the licensees for the Segas process, the main contractors taking part in the project, had begun work on erecting the gas-making vessels. These were prefabricated at the Corporation's factory at Stockton-on-Tees and brought to the site by road. In all there were 20 vessels. The air and steam preheaters were each 12 ft. 3 in. inside diameter by 34 ft. high, while the reactor vessel containing the catalyst had an inside diameter of 14 ft. 3 in.

To improve the flow of gases through these vessels venturi shapes have been incorporated in the throats of the reactor vessels. The gas from each unit passes to its own washbox, but the Lymn washer, carbon washer and Whessoe detarrer, are common to a pair of sets and from them the gas flows into the relief holder of 120,000 cu.ft. capacity, supplied by Clayton, Son & Co., Ltd., of Hunslet, Leeds. Two Holmes - Connersville meters measure the gas made on each gas-making cycle. When light distillate is used for gasification no tar is actually produced, but carbon is formed in its place, which must be extracted from the gas before it passes into the relief holder. By spraying the gas in the carbon washer with water the carbon content is reduced to 30 grains per 100 cu.ft.; and on leaving the electrostatic detarrer this has been further reduced to less than one grain per 100 cu.ft. From the relief holder the gas passes to the boosters or exhausters as they are known in the conventional gasworks. There are two of the Rateau type (one standby) with a capacity of one mill. cu.ft. per hour supplied by the Bryan Donkin Co., Ltd., and steam driven. The gas passes on through the naphthalene washer through the tower purifier plant, supplied by Newton, Chambers & Co., Ltd., to the Holmes-Connersville station meter where it is odorised with tetra-hydro-thiophene to the main holder of 2 mill. cu.ft. capacity supplied by Robert Dempster & Sons Ltd., of Elland. Gas is pumped by two Bryan Donkin compressors (one

In the girder work above the Lymn washer, showing the hydraulically operated valves. The complicated network of oil impulse pipes can be clearly seen.



The waste heat boiler plant, showing the three boilers and the waste gas main connecting them to the chimney stack. Unusual features are that the boilers are in the open and the main is both lagged and protected from the weather by aluminium sheeting.

standby) into the South London main through the new 36-in. main running along Watling Street. These compressors, also of one mill. cu.ft. per hour capacity, are of the Rateau type running at 8,000 r.p.m. and are driven through a David Brown gear box by D.C. electric motors. The compressor house is divided into two sections by a wall forming a gas-proof barrier through which the drives from the electric motors pass by means of gas-tight glands. In the electrical section are installed the necessary mercury-arc rectifiers supplied by Hackbridge & Hewittic Ltd., to convert the current from the A.C. mains to D.C. and all switchgear.

During the blow period, air is received from Keith-Blackman blowers at 60 in. w.g. There are three of these steam-driven by Greenwood & Batley turbines and each large enough to supply air to one pair of gas-making units, with one blower as a standby. Passing through the air preheater unit, the air enters the reactor unit where it burns off any carbon deposited increasing in temperature as it proceeds. Much of this heat is given up to the steam preheater from which it emerges at a temperature of about 650°C. to enter the hot gas mains. A bus main into which all hot gases from each gas-making unit pass, connects the hot gas mains with the waste heat boiler plant. Here three Spenser-Bonecourt boilers working at 200 p.s.i., one standby, raise about 80% of the steam needed by the plant. The remainder is supplied by the B.P. Kent oil refinery. The waste gases at 250°C. enter the waste gas main at the boilers and travel to the base of the 220 ft. prestressed concrete stack, lined with refractories, through a steel main lagged to prevent condensation and covered with aluminium sheeting for easy maintenance and protection from the weather.

The only by-products of the process are tar when using heavy oil, carbon when using light distillate and liquor from the washboxes. Carbon is recovered by allowing it to settle out in specially designed prestressed concrete settling tanks formed of precast sections. The tanks, circular in shape, are fitted with a special scraper gear by which the carbon can be separated from the liquid. The carbon is collected and taken to a vacuum filter for further dehydration before disposal. The hot liquor from the washboxes is run to a reinforced concrete, timber-packed cooling tower, supplied by the Davenport Engineering Co., Ltd., from which it is returned by the cool liquor pumps to the Lymn washers. Tar will be stored in overhead tanks when heavy fuel is used at some future date for gas making and will be duly disposed of.

There are no fuel feedstock storage tanks on the Board's site, but instead four 700,000-gal. tanks, two for light distillate and two for black oil have been built on the Kent oil refinery site and the necessary connections have been laid to ensure a constant supply of whatsoever feedstock is being used. That carrying the heavy oil is lagged and steam traced to prevent the high viscosity oil becoming sluggish in cold weather. A refinery gas main for heating the gas making plant completes the three fuel connections, laid in 8-in. steel pipe. The pumps supplying light distillate to the Segas plant are of Hayward Tylor & Co., Ltd.'s manufacture and those bringing heavy oil or disposing of tar have been supplied by Plenty & Son, Ltd. Other connecting services between the two sites are a 10-in. steam main bringing steam at 175 p.s.i., a 2-in. wash oil main to supply irrigating oil to the electrostatic detarrers and the naphthalene washer, and a 20-in. salt water main, carrying cooling

Above the steam preheater and the reaction vessel; note the special shape of the hood of the latter. Control gear impulse pipes can be seen in the foreground.

A general view of the Segas plant from the works offices. The relief holder appears on the extreme right, while the gas-making vessels are seen in the right background and the Lymn washer, the carbon washer and the electrostatic detarrers in the centre.

water from the refinery's main cooling system. Various spent oils will be returned to the refinery. Cooling effluent and other effluents from the plant are discharged through a 24-in. concrete main into the Colemouth Creek.

The supply of fresh water to the Isle of Grain peninsular is very restricted. The refinery has had to sink wells at Hoo to add to the available supply and lay a 12-in. connecting main. The Board's fresh water requirements are ¼ mill. gal. per day rising to ¾ mill. for the completed project. Since the refinery is also carrying out extensions, the total requirements may amount to 3 mill. gal. per day, and with the collaboration of the Medway Water Board an 18-in. supply main has been laid from Cuxton. Since this route is very similar to that of the gas main leaving the works, both mains have been laid for the greater part of the way in a common trench under the same contract. The supply to the gasworks will be by a 10-in. branch from the 18-in. main. The raw water as received is stored in the bottom half of a prestressed concrete water tower, which holds a day's supply. From here it passes to a Permutit water treatment plant working on the hydrogen ion starvation process. The treated water is pumped to the top half of the same water tower, where a day's supply can again be stored.

A feature of this works is the central control room in which all measuring instruments connected with the plant's performance are located. In here, too, are the hydraulic controllers for the Segas plant. By centralising all instruments and by making it possible to carry out all adjustments to the plant from this one point, a very great step forward in the control of gas-making plant as viewed by the gas industry has taken place. It has also made possible the running of a plant of large potential output with an exceptionally small labour force.

At the same time it has entailed putting an entirely new point of view before the plant operators. This in turn has meant the careful selection of the right type of men and their careful training. The operators have been taught to 'fly by instruments,' and to make all adjustments to correct any unusual conditions as shown by their instruments, by remote control. The training of the operators, which included their learning the elements of the flow of gases and liquids, as well as instrumentation, has been carried out by the British Petroleum Co., Ltd., at its refinery training school. All instrumentation, which works by pneumatic power, has been supplied by Elliott Bros. (London) Ltd. The control room may be divided into three sections; that which contains the hydraulic controllers, one for each Segas plant, by which valves are cyclically operated by hydraulic power to change from one operation to another; that which contains the recorders, from which adjustments to the plants performance can be made and certain rates of flow adjusted by pneumatically operated Fisher valves; lastly, the control room operator's desk on which are placed certain instruments on which his attention must be kept and from which any abnormal behaviour of the plant is immediately apparent. Included here, too, is an automatic electric typewriter which records hour by hour the flows of steam, air and feed stock to the individual units as measured by conventional flow meters. The operator will add up these hourly totals at the end of the day.

Since all the instruments are inferential, their accuracy must be periodically checked; so too must the alarm

system be proved at regular intervals. The responsibility for both these functions is shared by the process operator and his assistant. The former can produce alarm conditions under strict control and his assistant carry out the monitoring duties for checking instrument accuracy.

Air for working the pneumatic air instrument system is compressed by two electrically driven Broom and Wade compressors (one standby) at 80 p.s.i. It is stored at this pressure and released to the main air pressure lines at 60 p.s.i. to be reduced to 25 p.s.i. for operating the Fisher valves and the instrument lines.

The location of the central control room is on the further side of the No. 4 Segas unit. This has made necessary the bringing together of all hydraulic, pneumatic and electrical connections to one point from quite considerable distances. To do this as neatly as possible and to allow easy access of these connections, a prestressed concrete bridge has been built at the top end of the Segas units near the inlets to the waste-heat boilers. All pipe work and cabling over the bridge has been carried on Uni-strut carriers, manufactured by Sankey-Sheldon Ltd. The hydraulic pipe work between the hydraulic controllers in the control room and the Segas units is unique, in being the longest so far laid, there being a 200 ft. run to Nos. 1 and 2 units. To overcome pressure loss due to friction and other causes in these long lengths, the pipe used throughout is 2 in. o.d. Previously the largest pipe used was 1¼ in. o.d.

The control room has been built at first floor level, with the works' laboratories underneath to avoid 'dead legs' in the pipe work.

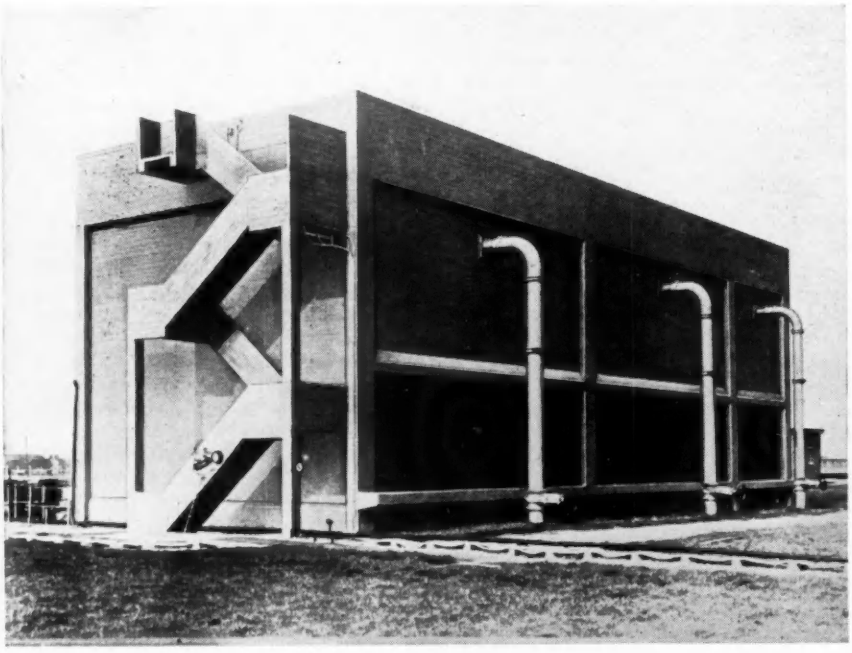
The hydraulic controllers themselves are the standard Power-Gas-Lockheed units with an extra train for purge steam added. All the hydraulic pressurising gear is contained in a part of the control room isolated from the main instrument room and allows the units to operate quite silently.

There is no instrument maintenance workshop at the works. The day to day maintenance staff can exchange service units for any faulty instrument. These latter will be returned to the makers for overhaul.

Maintenance generally at this works is carried out in conjunction with the refinery. Planned maintenance has been adopted so that the Segas plant has virtually become another section of the Kent Oil Refinery, which is responsible for its complete overhaul once a year. This has the advantage of keeping the Segas plant in the best possible condition to the greatest benefit of both the suppliers and the users of the feedstocks.

The labour force needed on this works can be kept far below that required for a carbonising plant of comparable size. There are six shift operators, three shift instrument operators with one relief in each case, a mechanical fitter, and instrument fitter, eight men on day work and four purifier men, a total of 24. There is a total staff of 18 including those employed at the works office.

All main plant machinery, except for the main compressors, has been installed in one building, termed the 'machinery room.' This comprises the plant boosters, the air blowers for the Segas units, the instrumentation air compressors, and the blowers for the air to the purifiers. A small control panel, manned continuously, keeps the operator informed of any changes in their performance, and allows full control without a great deal of unnecessary walking about. From the control panel there is a clear view of all machinery under the operator's charge.



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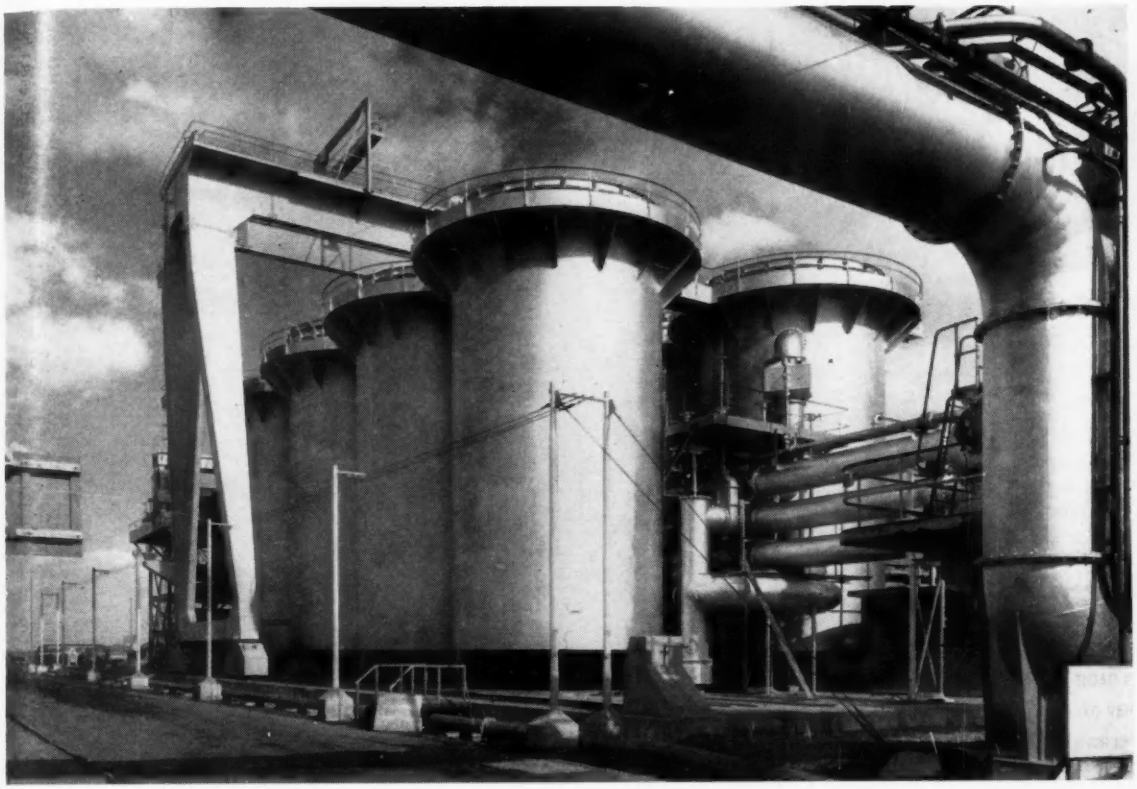


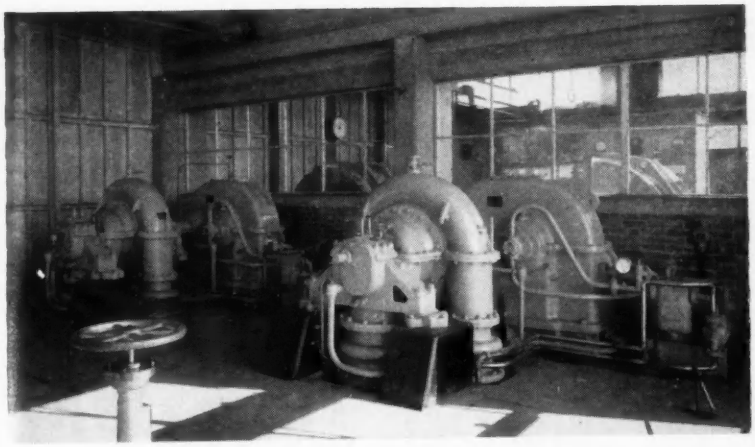
The tower purifier plant showing the two parallel gas streams and the Goliath crane constructed in box sections.

The plant has been commissioned in sections and has given remarkably little trouble during the early stages of starting up.

Certain difficulties arose from the presence of condensable hydrocarbons, which made itself felt by the sooting up of neat burners in domestic gas appliances. The trouble was detected by observing the abnormally broad band in the luminous flame caused by unsaturated hydrocarbons. A total proportion of 2.4% of which 2.1% was pure benzene (95-98%) was found. This was overcome by increasing the rate of oil flow through the naphthalene washer from 2,000 gal. per day to 24,000 gal. per day.

The substantial reduction of condensable hydrocarbons is essential since their presence in town gas is unsuitable for high pressure gas distribution systems and modern gas appliance manufacturers have undoubtedly taken advantage of their absence in the design of much of their most modern equipment.

The purifier plant consists of six towers, capable of being run as two streams or three towers or a single stream of six. The plant, supplied by Newton, Chambers & Co., Ltd., is equipped with the most up to date machinery for mechanically cutting out the spent or partly spent oxide and each oxide container is circular instead of octagonal, and fitted with a detachable central tube to make this possible. Two stocking towers are also included. The Goliath crane for handling the oxide containers is made of steel box sections in place of the more usual girder structure. This construction is proving satisfactory since little whip is detectable in the very considerable winds which occur in this area, nor is any crabbing noticeable. A British Jeffery Diamond disintegrator is included, so is a means of adequately wetting the oxide. This process has been found an efficient means of satisfactorily re-vivifying partly spent oxide which can be immediately reloaded into containers and



The two electrically driven Rateau compressors. In the background can be seen the dividing wall between the gas section and the electrical control room containing motors, rectifiers and switch gear.

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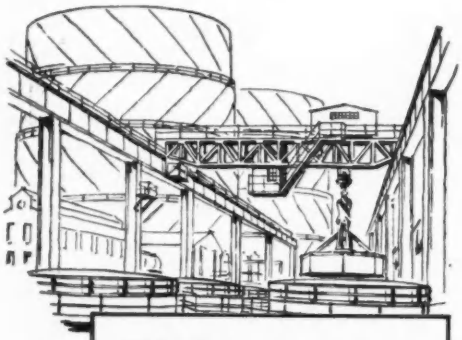
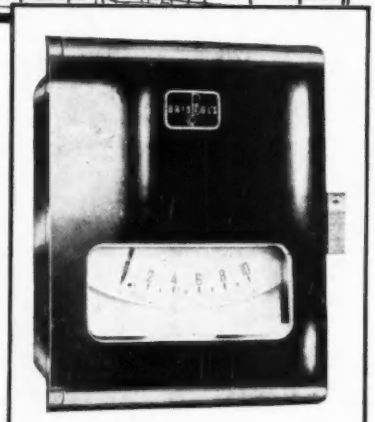
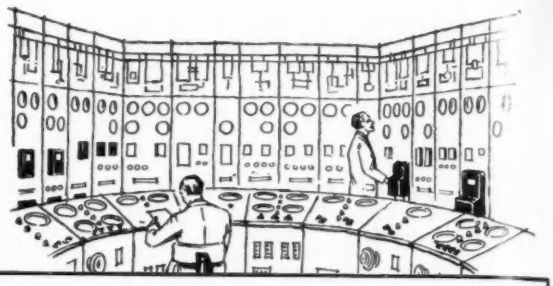
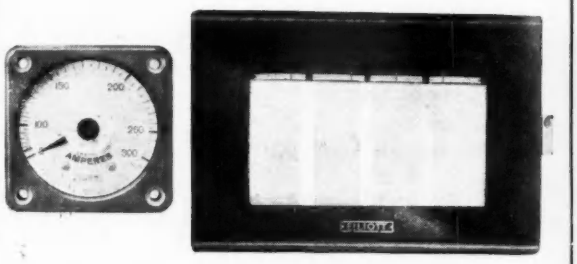




TELEMETERING Remote indication, recording and control of temperature, flow, pressure, level and gas holder stock.





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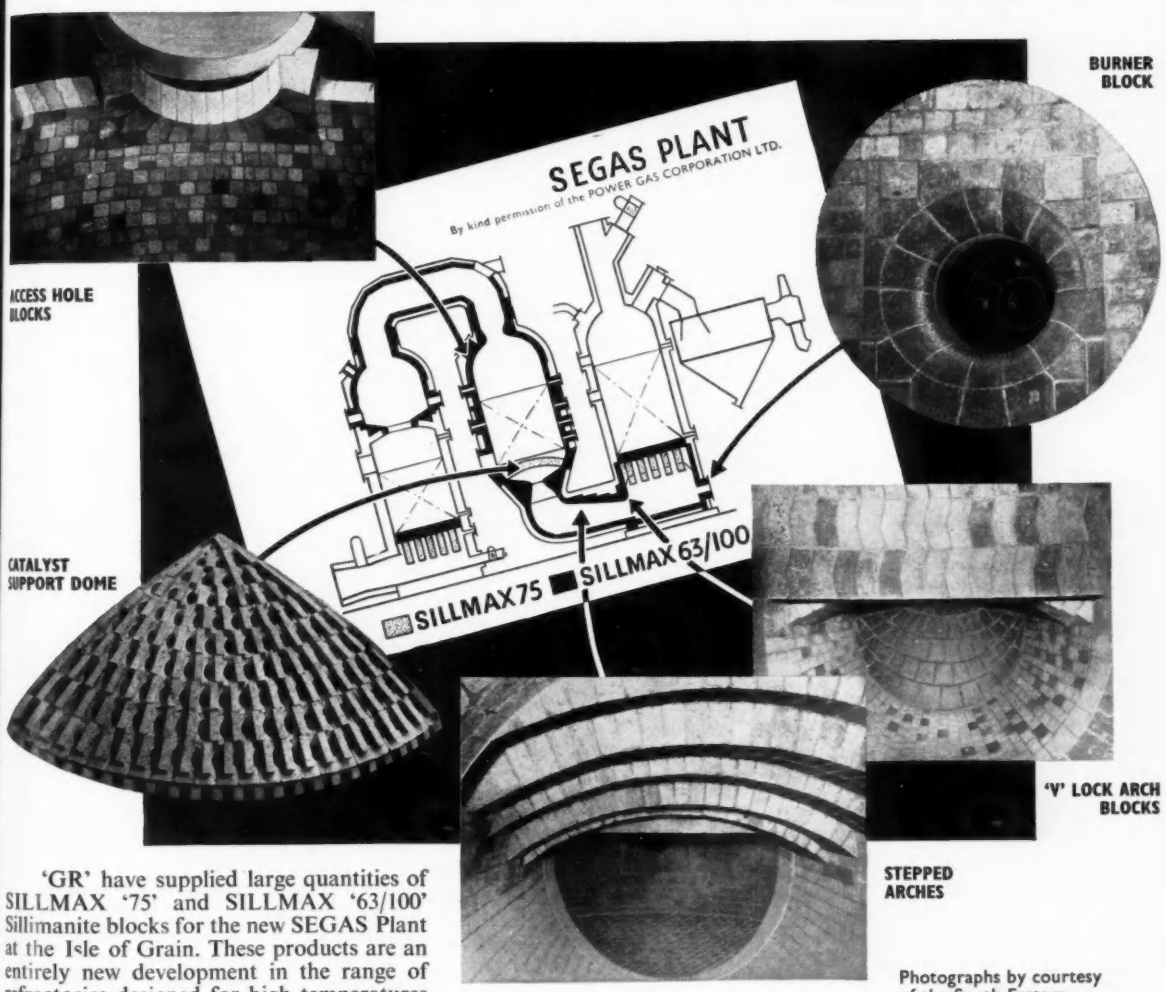

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Photographs by courtesy of the South Eastern Gas Board.

GR Technical Services Department is available for consultation by users in the selection and application of these and other refractories

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GAS from OIL

Reforming refinery gas

FOR the purpose of this paper, 'reforming' may be defined as the modification of a hydrocarbon gas, or gaseous mixture containing hydrocarbons of high calorific value so as to form a larger volume of gas of lower calorific value. This modification may be accomplished by simple cracking at high temperatures, or in addition to thermal cracking, the hydrocarbon gases may be caused to react with steam, oxygen or both. Complete reforming would be splitting up hydrocarbons so as to yield only carbon monoxide and hydrogen, such as the theoretical reaction of propane with steam at an elevated temperature:

$$C_3H_8 + 3H_2O = 3CO + 7H_2$$

Some systems of reforming depend solely on the thermal decomposition of the hydrocarbon. All gaseous hydrocarbons with the exception of methane decompose readily at high temperatures. Next to methane the most stable of hydrocarbon gases is ethylene, and this readily decomposes if heated to temperatures above 760°C. The decomposition of gaseous hydrocarbons can take place both in the vapour phase and in contact with hot surfaces, and since heat is usually absorbed during such reactions, it might be expected that if sufficient time be allowed for the gas to remain in contact with surfaces heated to between 800°C. and 870°C., the only hydrocarbon gas that will remain in any considerable amount will be methane. The reactions by which the cracking takes place are complex, but the final product will be a mixture of methane, hydrogen and free carbon, together with small amounts of aromatic hydrocarbon vapours such as benzene and naphthalene.

Efficacy of steam

The object of using steam in the pyrolysis of hydrocarbons to form fuel gases is, first, to increase the volume and total heat content of the gases produced from a given amount of feed hydrocarbons, and secondly, to modify the composition and thereby the specific gravity, heating value and burning characteristics of the product gas. The efficacy of steam in reducing the formation of free carbon in the cracking of hydrocarbons depends on the working conditions, but in favourable circumstances it can have a real value in reacting with carbon deposited on the heating surfaces, to form water gas. The reaction between steam and hydrocarbon gases and vapours is endothermic and unless a suitable catalyst be present scarcely occurs unless the steam itself be highly superheated.

The mechanism of the reaction between steam and a hydrocarbon may be as complex as that of thermal cracking but the overall reaction may generally be expressed in a simple manner; thus for methane,

$$CH_4 + H_2O = CO + 3H_2.$$

By this reaction 1 cu.ft. of methane with a net calorific value of 895 B.t.u.

From a paper by

W. J. CUTLER,
M.Inst.Gas E.

POWER-GAS CORPORATION LIMITED

to the London and Southern Junior Gas Association.

per cu.ft. yields 1 cu.ft. of carbon monoxide with a net calorific value 318 B.t.u. per cu.ft., and 3 cu.ft. of hydrogen with a net calorific value of 320 B.t.u. per cu.ft. or a total of 810 B.t.u. Hence, as a result of the decomposition of the methane and steam, the products have a combined net calorific value 233 B.t.u. greater than the methane used—this additional heat must be provided from an external source. For propane, the reaction would be:

$$C_3H_8 + 3H_2O \longrightarrow 3CO + 7H_2.$$

There would be 10 cu.ft. of products from 1 cu.ft. of propane and the total net heating value of the products is 529 B.t.u. greater than that of the propane. Again heat must be provided from an external source. An alternative possible reaction between methane and steam can produce carbon dioxide instead of monoxide thus:

$$CH_4 + 2H_2O = CO_2 + 4H_2.$$

In this case the total heating value, net, of the product 4 cu.ft. of hydrogen would be only 185 B.t.u. greater than the net heating value of the methane. Whether carbon dioxide in the product gases results from the direct reaction of steam with the hydrocarbon is of no real significance, since the water gas reaction,

$$CO + H_2O \rightleftharpoons CO_2 + H_2$$

at temperatures above 1,000°C., in the absence of a catalyst, or below this temperature in the presence of a catalyst, will promote the formation of carbon dioxide and hydrogen, from carbon monoxide and steam if sufficient steam be present. Steam can also react with the hot carbon on the heating surfaces, thus:

$$C + H_2O = CO + H_2.$$

The reaction $C+2H_2O=CO_2+2H_2$ is hardly likely to occur to any appreciable extent because of the unreactive nature of the deposited carbon. The final products contain, therefore, besides hydrogen and hydrocarbon gases from the pyrolysis, hydrogen, carbon monoxide and carbon dioxide from reactions with steam.

The addition of air, or oxygen, to the hydrocarbon being cracked usually has one or more of the three following purposes:

1. To avoid or reduce the formation of free carbon.

2. To furnish by combustion of part of the hydrocarbons some or all of the heat needed to carry on the cracking reactions.

3. To modify the composition of the cracked gases.

The first step of the reaction of oxygen with hydrocarbons is one of controversy in the theory of combustion. It is believed to include direct addition of oxygen to the hydrogen molecule, giving peroxides which are unstable. The decomposition of these yields formaldehyde, hydrogen and

carbon monoxide. The formaldehyde is thought to aid the oxygen in the further attack upon the hydrocarbons. Only traces of formaldehyde survive in the final products. If there is sufficient oxygen and the cracking is not too greatly accelerated by sudden exposure of the hydrocarbons to high temperatures, little free carbon is formed. The final products depend upon the temperature and ratio of oxygen (air to hydrocarbon) but include hydrocarbons, principally methane and ethylene, with some hydrogen, carbon monoxide and carbon dioxide and water vapour.

Oxygen balances

Calculations by oxygen balances from the results from the analyses of gases formed by cracking in the presence of air, show that in the reforming of natural gas where the air was added to increase the capacity of the apparatus and raise the specific gravity of the gas, about a quarter of the oxygen was used in the formation of water vapour, while in the production of gas from propane or from gas oil by methods in which the air is used to furnish heat for the cracking, approximately 40% of the oxygen was used to form water vapour.

A process for the reforming of oil refinery gas in the generator of a carburetted water gas plant, in which the carbon formed during the cracking of the hydrocarbon gases is deposited in the generator fuel bed and subsequently utilised for gas making, was developed during the period 1928 to 1930 by the United Gas Improvement Company, under the direction of J. A. Perry.

The object was first to utilise, at a mutual profit to the oil and gas industries, the by-product refinery oil gas and secondly, to provide by producing a reformed gas of variable specific gravity, a means of supplying a mixed gas of constant specific gravity in the territory where the base load gas was supplied from coke ovens.

The modifications made to the standard C.W.G. plant provided a means of admitting controlled amounts of refinery gas to the up and down runs on the plant, together with necessary alterations to the automatic controllers, to take care of the operation of extra valves involved.

Reforming cycle

The reforming cycle differs from that for carburetting blue water gas because it is not necessary to maintain high temperatures in the carburetter. They must, however, be kept sufficiently high in the fuel bed to crack the refinery gas—the exact cycle and rate of gas throughput varies with the character of reformed gas desired.

TABLE 1

Cycle—4 minutes	% of cycle	
Blow	17	20,000 cu. ft. per minute
Blow run	10	12,000 cu. ft. per minute
Up steam	6	350 lb. per minute
Back run steam	3	350 lb. per minute
Back run steam and oil gas	32	200 lb. of steam and 2,000 cu. ft. of oil gas per minute
Up run steam and oil gas	24	200 lb. of steam and 1,800 cu. ft. of oil gas per minute
Up run steam	5	350 lb. per minute
Blast purge	3	12,000 cu. ft. per minute

Control of the state of the fuel bed—this is most important for the decomposition of hydrocarbons in the gas and the control of the formation of lamp-black, tar and naphthalene—is attained by attention to such things as the air:steam + hydrocarbon ratio; and the steam:hydrocarbon ratio, with correct percentage of down-run as with normal water gas practice.

The Philadelphia Electric Co. of the U.S.A. have been reforming refinery oil gas in their C.W.G. plants at Chester, Pennsylvania, for a number of years.

Table 1 gives typical operating data from this plant when maximum reforming to the maximum extent, and producing a gas of a C.V. of 520 B.t.u. per cu.ft. and a specific gravity of .70.

Lamp-black

The 3% backrun steam before the refinery oil gas is admitted provides time for the backrun steam to purge the superheater and carburetter of blue gas, thereby ensuring the presence of steam to mix with the refinery oil gas as it is admitted at the top of the carburetter. Admitting the oil gas at the top of the superheater causes an increase in the calorific value of the reformed gas from the uncracked gas left in the carburetter and superheater at the end of the backrun. Lamp-black will be formed if the backrun refinery oil is admitted at the start of the backrun.

The determination of lamp-black is carried out by exposing a 3-in. filter paper held in a frame to a jet of gas from a $\frac{1}{8}$-in. petcock on the top of the carburetter during the uprun and on the backrun pipe during the backrun. A normal test paper shows a light brown to dark brown colour with practically no signs of black carbon. Lamp-black will show up very noticeably if it is being formed at any part of the cycle. The following results are average yearly operating figures:

Make per set per day—10 mill. cu.ft.

Generator fuel—7.2 lb. per 1,000 cu.ft.

Refinery oil gas—4.8 therms per 1,000 cu.ft.

Air—860 cu.ft. per 1,000 cu.ft.

Steam—23 lb. per 1,000 cu.ft.

Gas from sets, heating value—360 B.t.u. per cu.ft.

Specific gravity—.65.

H_2S—70 grains per 100 cu.ft.

Naphthalene—15 grains per 100 cu.ft

Finished gas, heating value—520 B.t.u. per cu.ft.

Specific gravity—.70

Organic sulphur—5 grains per 100 cu.ft.

Refinery oil gas, heating value—1,700 B.t.u. per cu.ft.

H_2S—150 grains per 100 cu.ft.

Specific gravity—1.02.

Efficiency of operation, gas output, coke and refinery oil gas input—91.5%.

The reforming operation is very flex-

TABLE 2

	Refinery oil gas	Backrun Reforming	Gas from sets		Finished town gas
			with blowrun	without blowrun	
CO_2	·7	2·4	6·6	2·4	5·6
Ill. (C_3H_6)	21·4	4·1	2·5	2·2	4·2
O_2	·7	·4	·3	·6	·6
CO	1·7	15·0	16·8	14·6	12·6
H_2	5·3	55·6	34·8	55·6	31·7
CH_4	26·0	20·8	13·8	16·9	10·1
C_2H_6	19·4	—	—	—	—
C_3H_8	17·8	—	—	—	—
C_4+	5·0	—	—	—	—
N_2	2·0	1·7	25·2	7·7	24·3
Sp. gr.	1·02	0·40	0·64	0·42	0·70
C.v. B.t.u. per cu. ft.	1,734	532	361	449	521

ible in itself and the same equipment can be converted to make it a water gas operation in a very short time. The blow-run can be varied to produce the finished gas at a C.V. of 520 B.t.u. per cu.ft. with a specific gravity as low as .49 or as high as desired. The operation can be varied from full reforming figures given above to blue gas with cold enrichment by varying the percentage of the cycle during which refinery oil gas is reformed. Thus depending on the availability and relative cost of coke versus refinery oil gas, the quantities used can be varied from 7.2 lb. and 4.8 therms to 25 lb. and 2.9 therms per 1,000 cu.ft. of 520 B.t.u. and .70 specific gravity gas. A typical gas analysis when using maximum reforming is shown in Table 2.

Heating value

Control of the heating value of the finished gas is obtained with a Cutler-Hammer calorimeter mixer, controlling a motor operated valve in a line supplying refinery oil gas to the reformed gas after it has passed through the Cottrell precipitators and naphthalene scrubbers.

During the summer of 1956, the Southern Gas Board began reforming refinery gas from Fawley at Southampton. Three units of the Power-Gas c.w.g. plant were modified for this purpose. Each generator has an internal diameter of 8 ft. 6 in. and the process, including cold enrichment has given an overall efficiency in the region of 85%. It is expected that complete results from this plant will be made the subject of a later paper by the officials concerned.

The partial combustion cracking process is one in which the hydrocarbon feed (usually preheated) is brought into contact with a limited amount of oxygen or air. The resulting combustion of part of the hydrocarbon feed gas provides the heat required to carry out the cracking reaction. Such processes are known as autothermic and may employ a catalyst. Generally speaking, all autothermic processes produce a reformed gas with a high nitrogen content and therefore, by town gas standards a high specific gravity. By a proper regulation of the proportions of hydrocarbons and air (or oxygen), the degree of thermal cracking may be controlled from a condition where a considerable portion of the hydrocarbon products such as the illuminants and methane still remain in the finished gas, to a condition where there is a complete conversion of the hydrocarbons to the products of partial combustion, the oxides of carbon and free hydrogen.

Processes under this heading are, (a) the Faber process, (b) the Koppers Hasche process and (c) the Distrigas process.

(a) *The Faber process.* The apparatus consists of a cylindrical, cone topped chamber lined with refractory and insulating brick. There is a heat exchanger for the air supply incorporated on the gas outlet pipe and the finished gas is taken through a conventional type wash-box. See Fig. 1.

The mixture of hydrocarbon feed and preheated air is introduced into the generator through a heavy steel pipe which, centrally placed, extends from the top of the generator to a point within a few inches above the base. The mixture of gases formed by partial combustion and cracking, leaves the top of the generator through a horizontal heat exchanger in which the incoming air is preheated to about 370°C.

The process can attain full gas making capacity from cold in less than one hour, the initial heating up being achieved by the insertion of an ignition torch through the ignition port located in the generator wall opposite the lower end of the feed tube.

The process is continuous, and when the necessary adjustments in the amounts and proportions of hydrocarbon feed and air are made, produce a gas of constant properties. Some typical analyses of reformed gas from oil refinery gas on a Faber plant at Olean U.S.A. are shown in Table 3.

TABLE 3

	Input refinery gas	Reformed refinery oil gas		
C.v. B.t.u. per cu. ft.	1,775	350	480	550
Sp. gr.	1·01	·796	·813	·830
CO_2	·4	1·9	1·7	1·5
Illuminants	12·7	5·3	9·7	11·8
O_2	—	·2	·5	·7
CO	1·3	13·0	10·2	8·5
CH_4	34·3	17·9	23·2	26·8
C_2H_6	49·3	—	—	3·0
H_2	2·0	13·7	9·1	3·5
N_2	—	48·0	45·8	44·2
Generator Temp. °F.		1,620	1,440	1,300
Thermal conversion efficiency %		88·7	89·1	86·00

It is claimed that the operation of the furnace may be carried out in either of two ways, (i) by the partial combustion method in which a reformed gas may be produced in a continuous manner or, (ii) by a method employing a heating phase (and therefore cyclic in operation), in which reformed gases high in hydrogen and carbon monoxide can be produced.

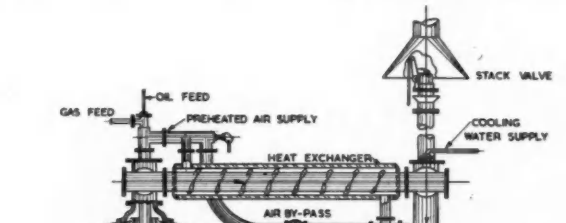


Fig. 1. Diagram of the Faber process for refinery gas reforming by partial combustion.

(i) The partial combustion method. The hydrocarbon feed, together with a regulated amount of air is fed through a three-way valve into one end of a regenerative mass where it is preheated to the ignition temperature and partial combustion occurs in the intermediate chamber. Product gases then leave through the second regenerative mass and give up most of their sensible heat, passing out at a comparatively low temperature through the second three-way valve. At definite intervals the three-way valves are reversed simultaneously, thereby reversing the flow of gas and giving continuous operation with a high heat efficiency.

By controlling the ratio of air to

(b) *The Koppers Hasche process* employs partial combustion, but differs in that it uses a special furnace employing the regenerative principle by frequent reversal of the direction of flow of the feed and product gases through the furnace. Rectangular in cross section it consists of three main sections—a centrally placed empty brick chamber flanked on either side by a mass of refractory regenerative tiles.

hydrocarbon feedstock a wide variation can be obtained in the depth of reforming and consequently heating value of the gas produced. Four typical analyses of gas produced by reforming propane are shown in Table 4.

It is claimed that other types of hydrocarbons, both lighter and heavier than propane, may be employed; for example natural gas reforms satisfactorily, as does natural gasoline, or light fuel oils. In fact it is claimed that any hydrocarbon that can be vaporised can be reformed.

(ii) In the 'heat' and 'make' cyclic operation there is no partial combustion since the necessary heat

TABLE 4

	1	2	3	4
CO_2 ..	1·4	1·6	1·6	1·6
C_2H_4 ..	0·6	0·4	0·3	0·2
C_2H_4 ..	13·9	14·1	14·0	11·7
C_3H_6 ..	3·6	5·9	7·2	7·5
O_2	1·7	1·2	1·2	1·2
H_2	8·5	9·0	8·4	7·4
CO	6·9	5·0	3·8	2·6
CH_4 ..	13·8	14·6	14·7	12·4
C_3H_8 ..	4·7	8·4	14.1	20·2
N_2	43·9	39·8	34·7	35·2
Sp. Gr. ..	0·9	0·92	0·96	1·01
C.v. B.t.u. .. per cu. ft. ..	637	753	946	1,028
Ratio of feed air : propane ..	2.1	1.6	1.16	1.09

is supplied by external sources. The hydrocarbon feed is mixed with steam prior to entering the furnace and the resulting gas is therefore high in hydrogen and carbon monoxide, and low in nitrogen.

Four-part cycle

The operating cycle is in four phases, each of the phases lasting approximately one minute. During a 'heat' phase (1), air from the blower enters one end of the reformer and burns with heating gas admitted to the centre combustion chamber, the products of combustion leaving the far end of the tile mass at a low temperature. After a short purge, the main three-way and four-way valves change over and the 'make' phase (2) begins with the admission of vaporised feed and steam at the opposite end, the gas made passing away to the gas cleaning train. These two phases are then repeated in the reverse sense, thus completing the four-part cycle.

(c) *The Distrigaz reforming plant* works on the principal of partial combustion and employs a catalyst. Basically the process consists of passing a controlled mixture of hydrocarbon feed, steam and air through a catalyst bed. The proportion of gas steam and air is adjusted, and a suitable catalyst used, to ensure that a chemical balance is obtained between the endothermic and exothermic reactions which occur. Typical reactions are as follows.—

The oxidation of hydrocarbons:

$CnHm+n/2O_2+2N_2$—$n\ CO+m/2\ H_2+2nN_2+q$ calories.

The steam-carbon reaction:

$C+H_2O$—$Co+H_2-28{\cdot}6$ calories.

Provision is made for by-passing some of the rich gas into a mixing chamber at the outlet of the plant; the calorific value of reformed gas is often in the region of 180 B.t.u. per cu.ft. and, unless it is intended to use this for dilution purposes, it has been found that a very satisfactory town gas can be produced by mixing the reformed gas with rich gas to obtain a gas of the desired Wobbe index,

Special injector

The rich gas, air and steam, enter the reformer under a grate which carries the catalyst, the mixture being distributed through a special injector, which ensures an even flow through the catalyst bed and prevents early thermal cracking of the rich gas. Reactions take place in the catalyst bed, the temperature of which is between 760° and 870°C. A number of catalysts are available, the type being chosen according to the nature of the feedstock and the requirements of the reformed gas. On leaving the catalyst bed, the gas passes through three heat exchangers where much of the sensible heat is taken up and returned to the incoming gas; final cooling takes place in a washer cooler.

Typical data obtained when reforming refinery gas is shown in Table 5.

TABLE 5

	Refinery gas	Reformed gas	Final town gas
C.v. B.t.u. per cu. ft.	1,700	175	450
CO_2	—	5·0	3·6
CnHm	41·0	—	11·3
O_2	—	·2	·1
CO	—	14·1	10·6
H_2	16·0	38·1	31·3
CH_4	38·0	1·0	11·2
N_2	5·0	41·6	31·9
Density (air : 1) ..		·65	·68

It is claimed that this process can also utilise natural gas and light spirit; in addition it can be employed for the direct production of gas for ammonia synthesis. In such a case the air utilised for the reaction should be super-oxygenated in accordance with the composition of the reformed gas to be obtained. In Belgium there is already an industrial installation operating in an ammonia synthesis works.

The most usual application, however, of this type of reforming process is the production of gas for town gas systems, in particular, for winter peak load production. Plants can be built in capacities up to about 8½ mill. cu.ft. per day per unit.

In the production of synthesis gas by reforming, the initial methane content should be reduced as much as possible. However when reforming for the production of town gas less stringent reforming is permissible so long as the maximum output of the desired gas from reforming and enrichment is obtained. For any given steam : methane ratio, thermo-dynamic equilibrium favours more complete reduction as the temperature of the system is increased. Thus, equal initial volumes of steam and methane will result in the formation of a gas containing 5% methane if the reaction reaches equilibrium at 980°C. At 816°C. the residual methane content is in the region of 18%.

Hitherto the attainment of the necessary high temperatures for continuous reforming has been subject to the limitations imposed by materials of construction. The early processes, which carried out the reaction by purely thermal means, were forced to rely on cyclical operation of regeneration furnaces (of the type used as blast furnace stoves), built of refractory capable of withstanding temperatures above 1,200°C. Below this temperature, thermal reaction velocity is too slow to permit economic operation.

Lower temperature

An alternative by the steam reforming reaction may be carried out in the presence of a suitable catalyst to assist the attainment of equilibrium in a shorter time and so permit the reaction to proceed at a lower temperature than would be possible with thermal cracking. Catalysts can also be made selective and so are able to influence certain reactions; for example, they can be chosen to minimise carbon deposition or other unfavourable reactions, or can be directed towards the production of certain end products.

Effective catalyst of this type have been developed during the past 15 years. Nickel is usually employed as the activating agent in catalysts for reforming hydrocarbons. The nickel usually being supported on a refractory base such as alumina, kieselguhr, or magnesite, the content of nickel varies up to a maximum of about 30%.

Since the processes employed produced, as an intermediate step, a mixture of hydrogen, carbon monoxide and carbon dioxide, it appeared that they might be adapted to the production of peak load gas by town gas

companies. Mixture of hydrocarbons ranging from methane to propane, can be converted to a gas suitable for distribution by enrichment with propane or butane vapour and possibly dilution with a limited amount of air or stack gases.

Sulphur free

Continous catalytic gasification is usually carried out in alloy steel tubes containing the catalyst, mounted inside a brick furnace setting. Gas or fuel oil is burned to produce an internal tube temperature of 700-980°C. Sulphur-free hydrocarbon gas or vapour, with an excess of steam is fed to the tubes and a gas of about 300 B.t.u. cu.ft. consisting chiefly of hydrogen, carbon monoxide and carbon dioxide is produced. Methane, ethane and propane do not tend to deposit carbon, but higher paraffins like butane tend to decompose and deposit carbon on the catalyst unless a modified catalyst and probably more steam are used. With even small concentrations of olefins carbon deposition can also occur.

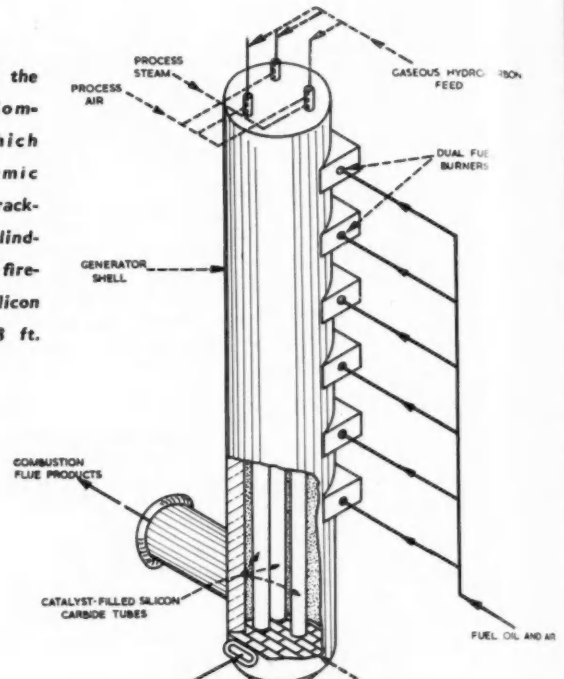


Fig. 2. Diagram of the Gas Machinery Company's reformer which works by endothermic continuous catalytic cracking. The vertically cylindrical shell, lined with firebrick, contains 4 in. silicon carbide tubes in 28 ft. lengths.

Thermal efficiency

In industrial practice the ideal of high temperature operation is countered by the considerations of expensive materials of construction and reduced thermal efficiency. To retain the latter at an adequately high level, heat exchangers should recover the sensible heat of the product gases. At the same time, the spent combustion gases employed inside the furnace should be utilised for the generation of steam in a waste heat boiler.

There are many types of endothermic continuous catalytic reforming plants on the market employing different variations of the same basic principle. The following are fairly representative and are briefly described.

(a) The Chemical Construction Corp. reformer.

(b) The Gas Machinery Co. reformer.

(c) The P. G. Hercules reformer.

(d) The Stark reformer.

(a) This type of reformer consists of a circular furnace in which are placed vertical high temperature alloy steel tubes containing the catalyst, together with burners to provide the heat required to maintain the reaction.

Product gases leaving this reformer when using natural gas as feed and operating at a catalyst temperature of 700°C. to 725°C., would have approximately the composition by volume shown in Table 6.

(b) The Gas Machinery Co. reformer makes use of silicon carbide tubes. The use of this heat conducting refractory material enables very high temperatures to be employed.

Catalytic operation can be carried out effectively at 700°C. to 925°C. This assumes, however, the use of a feed gas totally free of any sulphur compound. Such a gas is not always available to the gas undertakings and the low permissible operating costs preclude the use of expensive purification plant. It is, however, known that the adverse effect of limited amounts of sulphur in the feed gas can be overcome by increasing the operating temperature by 100°C. to 150°C.

Severe limitation

As already mentioned, one severe limitation on the use of extremely high temperatures has been materials of construction. In the continuous operation, it is necessary to transmit the heat of reaction through the walls of the catalyst tubes, and normally high alloy steels are employed for this purpose. However, these steels are costly, and only a few special metals are capable of withstanding temperatures above 900°C. Almost no commercially available steel is capable of exceeding temperatures of 1,040°C. This difficulty is overcome in this process by using the silicon carbide tubes, the necessary length of which can be obtained by a special method of joining a number of shorter tubes into one continuous length. See Fig 2.

TABLE 6

H_2	77%
CO_2	11·5%
CO	10·5%
N_2	0·6%
CH_4	0·3%
O_2	0·1%

Special design

Hitherto, the maximum length of silicon carbide tubes available commercially had been 68 in. The important new development is concerned in the method employed for joining such lengths of tubes together in a thermally and physically strong manner. The method depends on the special design of a ball and socket joint which is leak tight even without the use of a sealing compound. As a result, a flexible structure is obtained capable of allowing for lateral deflection of the tubes, and thus preventing the hazard of tube buckling.

It is claimed that the feed to the furnace can be remarkably versatile and ranges from gas oil and gasoline to natural gas. The make varies widely with the nature of feed and of operating conditions—amount of steam and/or air temperature—thus in the reforming of natural gas specific gravities have been obtained over the entire range of .35 to .6 and the

heating value range from 287 B.t.u. per cu.ft. up to the original heating value of the hydrocarbon feed, depending on the depth of cracking and the amount of nitrogen admitted.

(c) *The Power-Gas—Hercules reforming process* employs vertical tubes containing a catalyst. In this case the tubes, about 25 ft. in length, are made of special heat resisting alloy steel and are suspended in a refractory furnace of rectangular cross-section.

Particular aspects of this furnace are the countercurrent flow of the process gas and heating gas, and the firing of the furnace at a number of points, which enables the temperature of the tubes to be maintained at a correct gradient.

This process can use feed-stock containing a fair proportion of unsaturated material, and this is particularly important in that the effect of the carbon deposition is reduced to a minimum. The feedstock is heated to a point below which any thermal cracking can occur and with highly superheated steam passes through the critical range for carbon deposition up to reaction temperature, the two important factors being (1) this immediate transfer through the critical temperature range and (2) the presence of the necessary amount of steam to ensure that the predominant steam hydrocarbon reaction will give a carbon monoxide/hydrogen mixture without the production of free carbon.

Reforming furnace

The function of the reforming furnace shown in Fig. 3 is to react hydrocarbons with steam in the presence of a catalyst to produce hydrogen and carbon monoxide. This reaction is carried out within the tubes containing the catalyst at about 1,000°C., the reacting gaseous mixture reaching about 850°C.

TABLE 7

Constituents	Refinery gas %	Air/steam reformed gas (a) %	Steam reformed gas (b) %	Cold enriched gas (c) %
CO_2+N_2	9·2	—	—	—
CO_2	—	3·8	10·8	4·8
H_2	14·3	39·4	75·2	43·2
CO	1·2	17·8	14·0	13·4
CH_4	32·2	—	—	—
$C_2H_4+C_2H_6$	34·4	—	—	—
CnHm	—	—	—	3·6
C_3H_8	2·4	—	—	—
C_3H_6	5·9	—	—	—
C_4	·4	—	—	—
CnH_{2n+2}	—	—	—	10·2
O_2	—	—	—	·2
N_2	—	39·0	—	24·6
C.v. B.t.u. per cu. ft.	1,180	183	283	440
Density	·81	—	—	·63

High purity

In this country, this type of reforming plant is used mostly by the chemical industry for the production of high purity hydrogen from L.P. gases. In France there are many installations reforming natural gas for town use and in Rouen and Montpellier there are installations reforming refinery gas for towns use.

The results obtained from these plants at normal operation are shown in Table 7.

Each stream can produce in 24 hours (a) 1.32 mill. cu.ft. of air-steam reformed gas with the average composition shown in Table 7 and (b) .53 mill. cu.ft. of gas reformed by steam with an average composition also shown in Table 7, and (c) 2.1 mill. to 2.3 mill. cu.ft. per day of gas at 440 B.t.u. per cu.ft. is finally obtained by cold enrichment of the reformed gas from a gas of 1,250 to 1,450 B.t.u. per cu.ft. The average composition shown in (c) Table 6, refers to the gas distributed.

These streams can operate continuously at any output between 50 and 100% of the nominal capacity. On refinery gas the output can be carried to a peak of 120% of the nominal capacity. When the equipment is fed with butane the production of 1.9 mill. cu.ft. per day of gas enriched to 440 B.t.u. per cu.ft. is a maximum.

The overall efficiency, taking account of heating the air and the Hercules type tubes, is of the order of .92 with gas enriched to 440 B.t.u. per cu.ft.

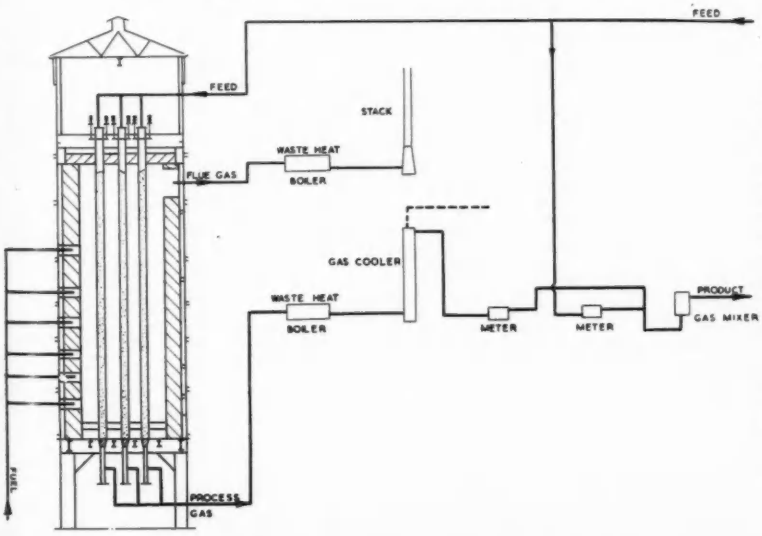


Fig. 3. Diagram of the Power-Gas-Hercules reforming plant employing vertical tubes filled with a catalyst and about 25 ft. long. The counter-current flow of heating gas and feed can be seen and the cold enrichment by untreated feed.

Flow meters

Control of air, steam and gas is effected manually by valves. Flow meters are installed on all fluid circuits. For any given setting of the control valves, any variation in the quality of the gas is corrected by a densimetric balance which acts on the gas pressure regulator to adjust the pressure of the feed. The equipment is stopped automatically in the event of loss of gas, steam or air, and in the case of excessive temperature of the air/steam/gas or gas/steam mixture entering the furnace, or of the catalyst. The streams are grouped as a unit, the various indicating and recording instruments—thermometers, manometers, calorimeters, density meters, flow meters—being collected in a light building. The streams are operated by an attendant and an assistant in eight hour shifts.

(d) *The Stark catalytic reforming furnace* is a process, developed recently by the North American

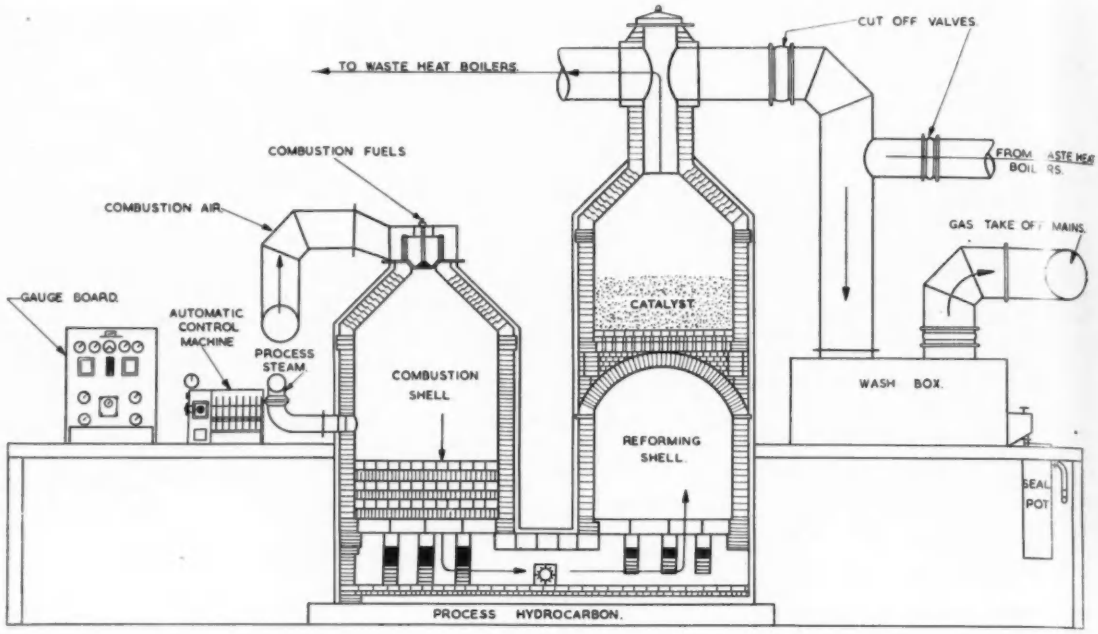


Fig. 4. The U.G.I. plant employing a cyclic catalytic process.

Utility & Construction Corporation and is mainly an attempt to overcome the use of long tubes, which in turn results in reduction of the height of furnace required.

The gas passages in this design are formed by a series of concentric steel walls which are free to expand in both directions. These walls form between themselves a series of annular spaces. The gas to be reformed together with steam, or steam and air, is introduced into the central cylinder and passed from one annular space to another, alternatively from the top or from the bottom of the concentric walls. The outer shell of the generator has a conical form and between this shell and the next cylindrical shell an appropriate amount of catalyst is located. The catalyst chamber formed in this manner has a section which increases gradually in area.

More constant

The principle on which the catalytic concentric furnace is based is fundamentally different from that of the tubular furnace. Design of the concentric type takes into account the increase in volume of gas when reformed, and to some extent provides for increasingly larger gas passages as the gas flows from inlet to outlet. It is claimed that this design ensures a more constant velocity of flow and longer time contact with the catalyst, which in turn allows operation at lower temperatures.

As the body of the furnace is subjected to different temperatures different qualities of steel are chosen to suit. The conical outer shell is in stainless steel resistant to a maximum temperature of 1,050°C. while the lower walls of the bottom plate are in stainless steel resistant to 800°C. The bottom of the collecting chamber is carbon steel. The whole body of the generator can freely expand because it is connected to the feed tube by means of an expansion joint.

The generator is located in a furnace having tangential burners situated in such a way as to bring heat to bear where required. One of these furnaces was installed in the gas plant of Gaz de France, St. Brieuc, France. The results of the official tests (April 27-May 1, 1954) showed satisfactory performance in respect of the guarantees given. A series of typical analyses made during the tests using a feedstock of 55.5% propane and 45.5% propylene are shown in Table 8.

TABLE 8

Constituents	(a)	(b)	(c)
H_2	49	51·8	71·2
CO	19·1	20	21
CH_4	3·4	3·5	0·2
CnH_{2n}	3·8	0·95	—
CnH_{2n+2}	4·0	0·15	—
CO_2	4·8	5·1	5·3
O_2	0·6	0·7	0·5
N_2	15·3	17·8	1·8

(a) Average of 16 samples of final gas after cold enrichment, (b) average of 42 samples of reformed gas (67% steam, 33% air) and (c) analyses of reformed gas with 100% steam reaction.

Cyclic processes for reforming are those which can usually also gasify liquid hydrocarbons and are characterised by intermittent operation of a 'make' and 'heating' phase. During the 'make' phase the hydrocarbon feedstock together with superheated steam are passed through a catalyst bed and during the 'heating' phase air is passed through the catalyst to burn off deposited carbon with or without the introduction of external heat by burners at suitable points.

The three most representative catalytic oil gasification processes are (a) the U.G.I., (b) the Onia-Gegi, and (c) the Segas processes.

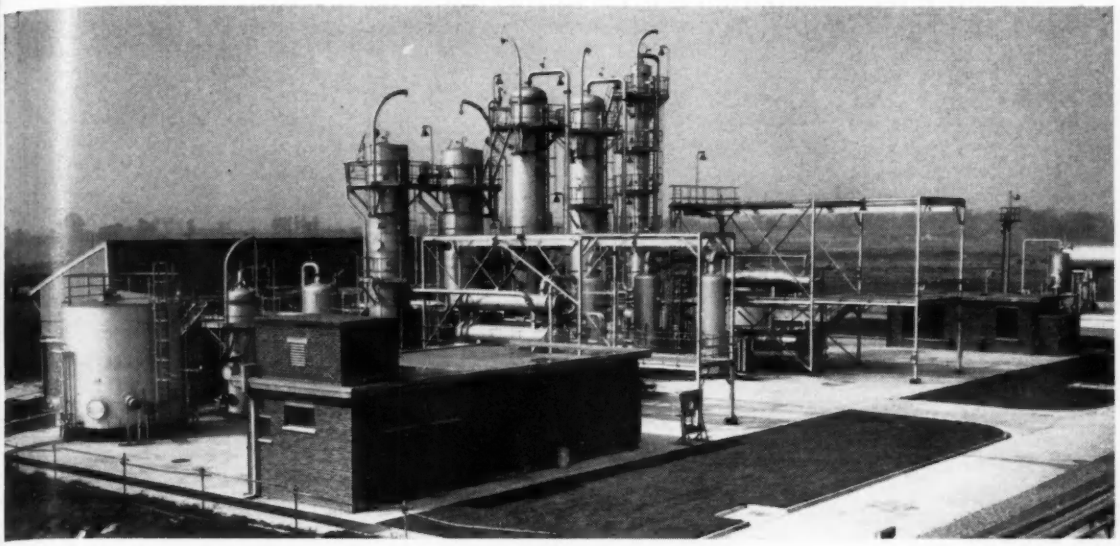
(a) In the U.G.I. process, shown in Fig. 4, the set consists of two refractory lined cylindrical vessels with auxiliaries. The combustion shell is equipped with a supply of air and hydrocarbon feed for heating, and steam for process requirements, in the lower portion of the combustion chamber, refractory checkers comprising a preheat section are installed.

Nickel catalyst

The reforming shell contains a single bed of nickel catalyst in the upper portion. This shell and the combustion shell are connected at the base by means of a refractory lined tunnel equipped with a source of supply of the hydrocarbons for process requirements.

The necessary control valves are hydraulically operated by automatic means. The heating portion of the

Continued on p. 137



Gas treating unit at Shell Haven.

Refinery gas production

GAS from OIL

From a paper by

A. K. DAVIS,
B.Sc., A.F.Inst. Pet.,

SHELL REFINING CO., LTD.

to the London and Southern Junior Gas Association.

PETROLEUM refineries operate on a feedstock which is generally given the name crude oil. In fact there are hundreds of different crude oils which vary considerably in their composition and properties. All of them are very complicated mixtures of hydrocarbons, ranging from the light gases (methane) right through to materials of very high molecular weights (greater than 700). Most of the products separated or manufactured from crude oil are themselves also quite complicated mixtures of hydrocarbons and it is only in the cases of gases and low boiling fractions that regular and complete composition analyses (in terms of individual chemical compounds) are undertaken.

Within the refinery the term 'petroleum gases' refers to those hydrocarbons which are normally vapour at atmospheric temperature and pressure. A list of these, together with their boiling points, molecular weights and heating values is shown in Table 1.

When produced from the ground, crude oils may contain large quantities of dissolved gas. Much of this gas is removed from the crude oil at the oilfields. This natural gas is an excellent fuel and where possible it is used as such. In America, for example, natural gas constitutes 95% of all gas distributed whereas in remoter parts some of the natural gas removed from crude oil may have to be burnt to waste.

Crude oils do not consist only of hydrocarbons; other components, some of which are regarded as contaminants may be present, incorporated in the hydrocarbon molecules. Sulphur is the principal contaminant and this may be present to the extent of 1½-2½% by weight in typical Middle East crude oils. Nitrogen, oxygen, sodium, vanadium and/or other metals may be present in minute quantities.

The primary process in all crude oil refineries is distillation, whereby the main products contained in the parent crude oil are separated from one another in terms of their different boiling ranges. Virtually no chemical changes occur during this distillation. Any gas in the crude oil which has not been removed at the oilfields will normally be separated during the primary distillation and may be recovered as vapour or partly as vapour and partly as liquid. Table 2 shows typical compositions of gases recovered during the distillation of Kuwait crude oil and from other refining operations. In a refinery processing 3 mill. tons a year of Middle East crude oil about 190 tons per day of such gases will be produced during the distillation step.

Unfortunately many of the products of crude oil distillation are not of a high enough quality to be fed directly to the customer. Also the proportions of the different fractions are not in balance with the market requirements. In particular, the octane number of gasoline and its percentage yield on crude oil may both be inadequate. The octane number is one of the figures indicating the performance of the gasoline in the motor. Hence processes have had to be developed whereby heavy oil fractions and/or low octane gasolines are subjected to

chemical change (conversion processes) in order to produce new high quality products which were not present in the original crude oil. In addition to gasoline fractions, gases are also produced in these processes. Several of these conversion processes involve 'cracking'—a mechanism by which large hydrocarbon molecules are broken into two or more smaller molecules. This may be brought about by heat either with or without the aid of catalysts. During these cracking reactions some very small molecules are formed and these appear as gases. Crude oil may contain some aromatic compounds but otherwise it consists of saturated hydrocarbons. In contrast, the products of cracking contain considerable quantities of unsaturated hydrocarbons—olefines. Table 2 also shows the analysis of the gases produced in a fluid catalytic cracking unit such as is installed in the Shell refinery at Stanlow, Cheshire. It will be seen that the content of olefines is very high, amounting to approximately 50% of the gases produced. These olefines are very reactive compounds and have become valuable as feedstocks to other chemical processes within the refinery.

TABLE 1
Properties of hydrocarbon gases

	Molecular weight	Boiling point °C.	Heat of combustion B.t.u. per cu. ft. gross at 30 in. Hg and 60°F (dry)	Density relative to air
Hydrogen	2·016	—	324·9	·07
Methane	16·04	−161·4	1,015·0	·55
Ethane	30·07	− 88·3	1,795·0	1·05
Ethylene	28·05	−103·9	1,615·0	·97
Acetylene	26·04	− 83·6	1,498·0	·91
Propane	44·09	− 42·3	2,571·0	1·55
Propylene	42·08	− 47·0	2,380·0	1·48
Methyl acetylene	40·06	− 23	2,212·0	1·38
n-Butane	58·12	− ·5	3,402·0	2·08
2-Methyl propane (isobutane)	58·12	− 10·2	3,382·0	2·08
Alpha butylene	56·10	− 6·1	—	—
Beta butylene	56·10	1—2·5	—	—
Isobutylene	56·10	− 6	3,172	2·00

Platinum catalyst

Another method of producing very high octane number gasoline components involves the use of a platinum catalyst. This is a powerful dehydrogenation catalyst which converts saturated hydrocarbons to aromatic compounds with the evolution of hydrogen. Some cracking also occurs but in the presence of high pressure hydrogen all the products of cracking are saturated and no olefines are produced. Several processes involving a platinum catalyst have been developed during the past few years, one of the best known being the 'platforming' process developed by the Universal Oil Products Company. The gases from the platforming process are usually recovered in two streams, one of which is very rich in hydrogen (80-95% by volume). Typical compositions of these streams are also given in Table 2.

These are the main sources of hydrocarbon gases in the refinery and it may be said that originally these gases were produced as by-products from operations which were carried out on behalf of some other specific product or products. However, the uses to which these gas fractions can be put have increased so much over the past few years that it is sometimes necessary to operate some of the above processes principally for gas production. In some refineries even this may not be sufficient and special processes may have to be installed for converting liquid products into gaseous fractions. Many processes for the gasification of oil fractions have been developed and installed by the gas industries of this and other countries. Most of these processes are cyclic in their operation, involving a make period followed by a heating or regeneration period. Such a method of operation does not greatly appeal to the petroleum industry which is so accustomed to continuous processing.

Two of the most modern gasification methods are the partial oxidation processes developed by the Texas Company and by Shell. In the Shell gasification process any hydrocarbon fraction down to the heaviest oils may be gasified continuously by burning in a special reactor with oxygen or oxygen-enriched air. The products consist predominantly of hydrogen and carbon monoxide. As installed at Shell Haven the gas will be used for the synthesis of ammonia but the process can be modified to yield a product suitable for use as town gas. A feature of the Shell process is the use of the heat released in the partial oxidation step to generate high pressure steam. Hence a high thermal efficiency is obtained.

The methods by which the various refinery gases are recovered and treated depend to a large extent upon the uses to which they will subsequently be put. These uses are discussed below:

1. Large quantities of butane and butylene are incorporated in motor gasoline blends. In addition to providing the volatility necessary for easy starting, butane and butylene have very high octane numbers. Since gasoline components are priced according to their octane numbers, this means that those butanes/butylenes which can be incorporated in motor gasoline acquire very high values. The butane/butylene fraction used in gasoline must be sweet smelling and non-corrosive and requires treatment before blending.

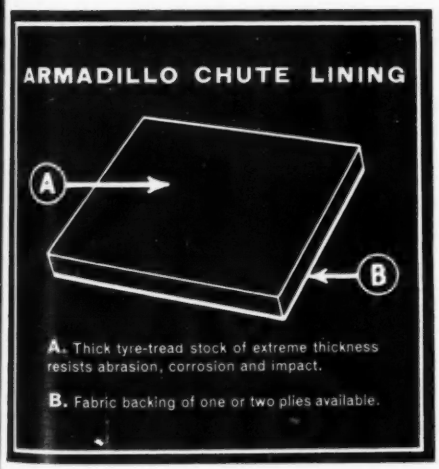
Simple and cheap

2. Refinery gases make excellent, clean fuels and it is not surprising, therefore, that refineries themselves use them to a large extent in their boilers and furnaces. This is easily achieved, no treatment is necessary and the distribution system is simple and cheap. Conventional gas holders are notable by their absence from refineries and the gas is, in the majority of cases, used as it is produced. If

TABLE 2
Analyses of various refinery gas streams
(after removal of H_2S and other contaminants)

% by weight	Gas from crude oil distilling (Kuwait)	Gas from catalytic cracking	Gases from catalytic reforming-(platformer)		Thermal reforming
			1	2	
Hydrogen	—	1·0	20·3	0·3	—
Methane	0·3	7·6	23·8	1·1	14·4
Ethylene	—	3·4	—	—	18·0
Ethane	8·7	8·4	30·8	10·3	
Propylene	—	17·7	—	—	12·2
Propane	27·0	12·9	13·4	32·2	22·9
Butylenes (normal and iso)	—	26·2	—	—	15·8
Butanes (normal and iso)	64·0	22·8	11·7	56·1	16·7

DEFEAT ABRASION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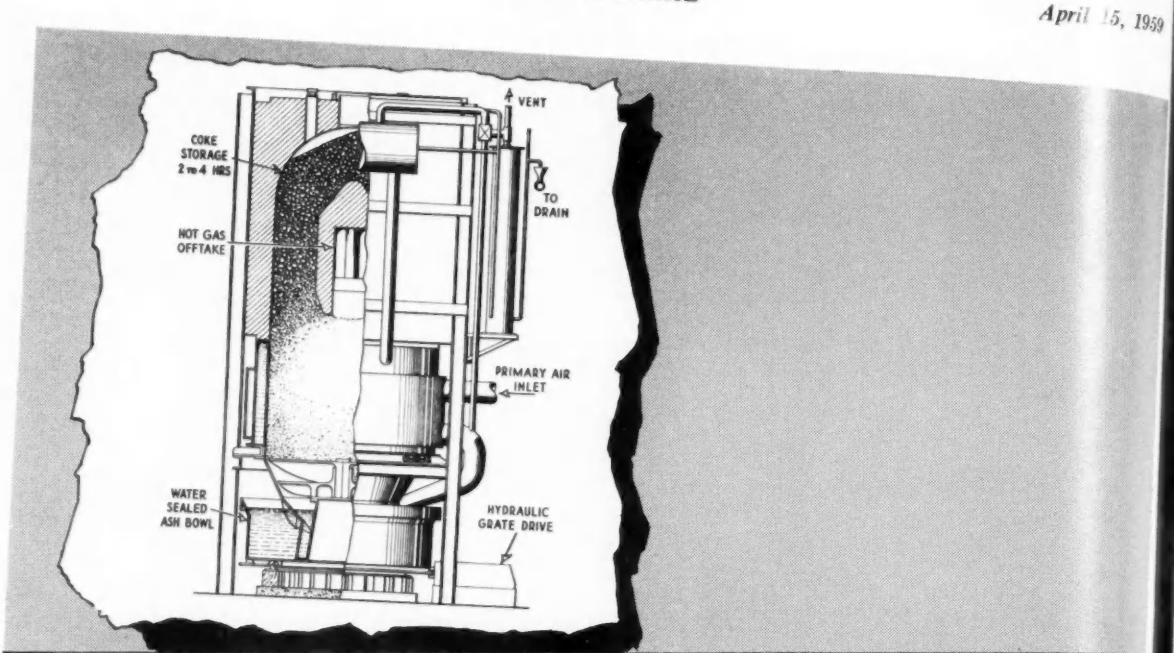

DEVELOPMENT REPORT

WEST'S "HOT GAS" MECHANICAL PRODUCER

The proved advantages of the flat grate have been combined with those of continuous ash extraction to give maximum performance in minimum space. These modifications have provided significant gains in potential output and permitted further simplification of the unit to give reduced maintenance of mechanical components.

The 6 ft unit now has a continuous rating in excess of 45 lb. dry coke/sq.ft per hour on run-of-retort fuel and screened fractions down to ¼". Efficiency of dust extraction is maintained at well over 90%.

The overall dimensions of the producer are retained and any existing installation can be modified to the new arrangement.

FOR FURTHER INFORMATION ON THE PRODUCER APPLY TO:

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London: Columbia House, Aldwych, W.C.2 Tel: HOLborn 4108
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MPI

storage of gas is required, this is done in liquid form under pressure, the liquid being subsequently vaporised as required.

3. Once the gas is in liquid form it becomes an easily transportable fuel and has found an ever expanding market as liquefied petroleum gas (L.P.G.). These fractions usually consist of propane or butane or mixtures of the two and are marketed under various trade names such as Butagas, Bottogas, etc. They are supplied in pressure containers and chemical treatment of the L.P.G. is necessary before filling in order to meet the rigid specification requirements with respect to water, sulphur bodies, etc.

4. Mention has already been made of the olefine gases produced by the various cracking processes within the refinery. These hydrocarbons are very reactive and make excellent feedstocks for chemical processes whereby innumerable synthetic products can be made. The simplest operations involve the reaction of olefines with themselves to form high octane polymer gasoline or with iso-butane to yield premium aviation gasoline components. In the chemical field, theylene, propylene and the butylenes have become the basis of a new industry—petrochemicals. A vast number of chemicals are now produced from petroleum gases including alcohols, solvents, detergents, plastics, etc. Refinery gas may also be used as a source of synthesis gas for the manufacture of ammonia, this in turn leading to the production of nitric acid, urea and other nitrogenous fertilisers.

Contaminants

5. Within the refinery increasing attention is paid to improving the quality of finished products. This involves the removal of harmful contaminants which may be present in only small amounts. These contaminants may be derivatives of sulphur, nitrogen or oxygen and a very satisfactory method of removing these is by hydrogenation at high pressure. This is carried out at high temperatures in the presence of catalysts, the contaminants being removed as hydrogen sulphide, ammonia and water. Hydrotreating, as these processes are generally called, has become a commercial proposition as a result of the availability of hydrogen gas within the refinery as described above.

6. Petroleum products have always been transported cheaply and conveniently in pipelines. Thus it is not surprising that gases should be supplied as feedstocks to other industries in the vicinity of refineries. In this country Shell refineries are supplying gas to outside concerns for the manufacture of carbon black and tetraethyl lead. A recent venture in the sales of refinery gas is the agreement to supply the North Thames Gas Board at Romford, Essex, with gas from the Shell Haven refinery 17 miles distant.

The hydrocarbon gases which we are considering, are produced together with the vapours of heavier hydrocarbons, *e.g.*, gasoline. A simple separation of the gases from heavier hydrocarbons can be achieved by cooling and partial condensation but the separation is far from perfect. Some of the gas fractions condense with the gasoline while appreciable quantities of gasoline vapour remain in the gas stream. This is because the composition of the vapour phase is related to that of the liquid phase by the relative volatilities of the individual components. Such an imperfect separation may be acceptable in some circumstances, for example where the gases are to be used only as a refinery fuel and where maximum recovery of gasoline fraction is not essential. In the great majority of cases, however, it is necessary to effect an efficient separation between the liquid fractions and the gases and to follow this with an efficient separation of the individual gases themselves. This requires the use of fractional distillation, which secures a sharp separation through repeated evaporation steps followed by condensation of the separated vapours. These successive evaporations and condensations are carried out on trays, often of the well known bubble cap construction, as many as 70 being combined in a single distillation tower. By this means very good separation can be obtained.

After a preliminary separation from the main crude oil stream, the gasoline and low boiling fractions are fed to a stabiliser column operating at about 175 p.s.i.g. pressure. Butanes, propane and the lighter gases are driven off overhead, are completely condensed and collected as a liquid. Butanes with a purity of about 99% mole are separated as the bottom product of the succeeding column which operates at about 275 p.s.i.g. The condensed overheads from this column consist of propane and the lower boiling fractions. High purity propane (98% mole) can be separated from these condensed overheads in a de-ethanising column. Although this column operates at 400 p.s.i.g., using conventional water coolers, it is only possible to condense the amount of overheads required as reflux liquid provided that the overheads contain a certain proportion of propane. This means that some of the available propane leaves in the overhead gas stream and consequently a very high recovery of propane liquid from the column bottom is not possible. If a high recovery of propane is required, it is necessary to produce a reflux liquid containing little or no propane. This in turn calls for very high pressures and/or refrigeration of the coolant used in the overhead condenser, or, alternatively, the use of a separate higher boiling liquid as reflux liquid (*e.g.*, gasoline). In the latter case the distillation process is usually referred to as absorption and very high recoveries of propane (greater than 97% by weight) can be achieved. However, a further distillation step is then required in order to separate the propane from the absorbing liquid.

Sharp separation

Very high pressures and/or refrigeration are required in fractional distillation in order to effect a sharp separation between propane and the lighter gases. Both these requirements involve considerable expense in terms of equipment and operating costs. The same degree of separation can be more economically achieved by selective absorption of the desirable fraction in a high boiling liquid, 'lean oil.' Absorption is carried out in a column, the design of which is similar to that of a fractionating column. Lean oil is fed to the top of the absorber, taking the place of the reflux liquid used in normal fractionating service. The gas mixture to be separated is introduced at the bottom of the absorbing column and is contacted countercurrently with the lean oil, which may be a heavy gasoline fraction. The solubility of the different gases in the lean oil varies with their volatility, the heavier gases—*e.g.*, propane — being much more soluble than the more volatile components—*e.g.*, methane and ethane. The absorbing liquid on reaching the bottom of the absorbing tower will contain practically all the selected heavy gas component but it will also contain small quantities of the more volatile gases. These are removed by feeding the liquid to a stripping column fitted with a reboiler. Frequently the absorbing and stripping columns are incorporated in one tower. The 'fat oil' leaving the bottom of the shipping section then contains the bulk of the selected gas, about 97% of that present in the feed gas, and it can be recovered from the absorbing liquid by normal distillation. The gases leaving the top of the absorbing tower contain very little of the selected heavy gas component but they do contain appreciable quantities of lean oil vapours. To prevent heavy losses of lean oil with the top gas, a sponge oil section

is mounted on top of the absorber. In the sponge oil section a heavy liquid such as gas oil is used to scrub out any lean oil vapours. Absorption is favoured by high pressure and low temperatures. However, the conditions normally employed in refineries (300-350 p.s.i.g. and 10-30°C.) are more easily obtained than the very high pressures up to 600 p.s.i.g. and extensive refrigeration which would otherwise be required to effect the same gas separation by fractional distillation.

It has already been pointed out that crude oils contain small amounts of contaminants, these being predominantly sulphur, nitrogen and oxygenated compounds. Some of these contaminants appear in the refinery gas fractions either in the form in which they occur in the crude oil or as decomposition products resulting from heating of the crude oil fractions. Principal among the contaminants found in refinery gases are the acid gases including hydrogen sulphide, H_2S, methyl and ethyl mercaptans CH_3SH and C_2H_5SH, and carbon dioxide, CO_2. Neutral carbonyl sulphide, COS, ammonia and other nitrogen compounds may be present in some of the steams in addition, of course, to water.

Alkaline reagents

The bulk of these contaminants will have to be removed if the gas fractions are to be used for anything except refinery fuel. Failure to do so may result in the product being corrosive, of bad odour and even toxic. When the gas fractions are to be further processed, the removal of contaminants is essential in order to prevent damage to catalyst activity. The acid contaminants can be removed with the aid of a number of alkaline reagents. With some of these reagents the reaction with the acidic contaminant may be reversible and in such cases a regenerative process may be possible. In other cases the spent alkali cannot be regenerated and must be disposed of. Carbonyl sulphide is a neutral compound but it is hydrolysed to CO_2 and H_2S so that removal by caustic soda is possible. Any alkaline contaminant can be easily removed by washing with an acidic reagent such as very dilute sulphuric acid.

Whatever treatment is selected, it will invariably be necessary to effect a close and prolonged contact between the treating solution and the gas fraction. If the gas fraction is to be treated in the vapour state, it will be possible to effect the necessary contact in a bubble tray column, a packed tower or even a spray column. Liquid fractions will normally be treated in a packed tower, but contacting is also possible in other specially designed devices such as rotating disc contactors, mixing nozzles, orifice mixers, etc. Treatment with chemical solutions leaves the gas fractions saturated with water and for many applications drying will be necessary. This may be carried out using solid absorbents or liquid absorbents such as di-ethylene glycol.

In view of the interest stimulated by the recently completed project to pipe refinery gas from Shell Haven refinery to the North Thames Gas Board at Romford, Essex, the new gas treating and distribution facilities at Shell Haven will be considered in some detail. Gas streams are available from the distilling units, a thermal reforming unit and from a U.O.P. platformer which upgrades gasoline. Liquid propane is produced at the distilling units and is fed directly to a treating unit where corrosive acid gases and sulphur bodies are removed by an alkaline wash. Drying with calcium chloride dessicant yields a product suitable for L.P.G. and the treated propane is stored in horizontal pressure vessels referred to as 'bullets.' Liquid propane is delivered from here to the L.P.G. plant whence it is delivered either in bottles or in bulk wagons. Liquid butane is produced at the distilling units and a butane/butylene stream is also available from the thermal reformer. Either or both streams can be fed to another treating unit for the removal of sulphur bodies, using an alkaline wash.

Those gases which are produced in the vapour phase are all available at pressures of 200 p.s.i.g. or more and are collected together in the high pressure gas main operating at 150 p.s.i.g. A typical analysis of the combined stream is shown in Table 3. The amount of gas required for sales is fed to the treating unit, the balance being reduced in pressure and passed to the low pressure gas main which is used to supply the furnaces of the various operating units and boilers. The gas production from the different producing units is not steady but varies from hour to hour. In order to smooth out these fluctuations in production, some gas (propane and/or butane) is stored in liquid form and is fed back into the low pressure main via a vaporiser and a pressure controller, thus maintaining a steady pressure of 45 p.s.i.g. The same vaporiser can be used to feed propane and/or butane vapour into the feed to the gas treater for adjustment of the hydrocarbon dew point of this stream. Protection against over pressuring is provided by a pressure control valve which opens to the safety flare.

At the inlet to the gas treater, the combined gas stream contains H_2S and other sulphur bodies which make it unacceptable to the North Thames Gas Board. The treating unit at Shell Haven has been designed especially to give a product that will meet the rather severe specifications of the Board with a good safety margin. This called for the removal of hydrogen sulphide, mercaptans and carbonyl sulphide, followed by the removal of water. Hydrogen sulphide could be removed from the gas stream by a non-regenerative caustic soda wash. Instead a regenerative process using an amine, *e.g.*, di-ethanolamine, has been installed. This results in lower chemical costs and provides a bigger buffer against fluctuations in the H_2S content of the feed gas. It also has the advantage that the H_2S can be recovered as such during regeneration of the solution and can be fed to a sulphur recovery plant. Absorption with di-ethanolamine is carried out countercurrently in a bubble cap treating column where the H_2S content of the gas is reduced to a few parts per million. A subsequent two-stage treatment with dilute caustic soda solution (10° Bé) in a second bubble cap column removes the remainder of the H_2S and reduces the mercaptan and COS contents to very low levels. Hydrogen sulphide cannot normally be detected in the treated gas—less than .1 ppm.—and the only further treatment required is the removal of water. For this a solid dessicant has been chosen—activated alumina. Two drying towers are provided, one being in operation while the other is being regenerated by passing a heated side stream of gas through it. Regeneration of the di-ethanolamine solution is carried out using steam in a third bubble tray column.

A metering station has been provided at the outlet of the treater in order to accurately measure the quantity and quality of the treated gas. The gas is then passed into the Board's main which operates at a pressure up to 120 p.s.i.g.

TABLE 3

Hydrocarbon analysis of typical feed to gas treating unit after removal of sulphur compounds.

	% by vol.
Hydrogen	30·3
Methane	18·0
Ethylene	1·2
Ethane	19·9
Propylene	5·8
Propane	19·5
Iso butane	1·2
n-Butane	2·6
Butylenes	1·5
	100·0

NORTH THAMES ANNOUNCE DOMESTIC HEATING AND HOT WATER TARIFF

A NEW domestic heating and hot water two-part tariff was announced by Mr. Michael Milne-Watson, C.B.E., Chairman of the North Thames Gas Board, at a meeting of the area Consultative Council last week.

The tariff, effective from May 1, provides for a fixed quarterly standing charge of £3 for the credit consumer, to include meter rent, and a commodity charge of 16d. a therm. The amount will be payable four times a year, irrespective of consumption. In the case of prepayment supplies, the standing charge would be 4s. 4d. a week, and in addition to the commodity charge of 16d. a therm, there would be the usual supplemental charge of 2d. a therm on the first three therms a week.

All other tariffs will remain unchanged.

In his statement to the Council, Mr. Milne-Watson said: 'For some time we have given much thought to that section of the market which covers the heating of business premises and homes and the provision of hot water in them and we intend more and more to develop this field.

'Early last year we introduced, for the benefit of non-domestic consumers, a central heating and central storage hot water two-part rate, which has proved popular and is bringing in new business.

'Since then we have been giving further study to the needs of the domestic market. More than half our gas is sold to the domestic consumer and it is of paramount importance that we should maintain domestic consumption as a solid foundation of our total load.

'There are many domestic consumers with large gas consumptions; we are convinced that there are many more who would use gas in larger quantities if a favourable rate was available to them. We have decided, therefore, that there is scope for another tariff designed to encourage the potential demand and to meet competition from other fuels in houses and flats.'

Mr. Milne-Watson then introduced the new tariff. He went on to say that perhaps he should make it clear that this new tariff would cover all the domestic uses of gas, including cooking and refrigeration, but as its name showed it was directed to meeting the need that the Board knew existed for improved service in central heating, hot water and warm-air heating.

'We already have the advantage that gas is a high-grade fuel on tap and needs no storage,' said the Chairman, 'and we hope to profit from that with this tariff, which will give to a good service the further advantage of an attractive price.

He said that the Board was glad to be responsible for an experiment which has made history by bringing a cargo of liquefied gas across the Atlantic ocean. Technically, the trip was a complete success. The Methane Pioneer had arrived back in the Gulf of Mexico and was being examined and tested, prior to bringing another cargo of 2,000 tons of methane to Britain when testing was complete.

A new concept of manufacture

Continued from p. 113

put back in a stocking tower. A tower takes two days to change.

Other buildings on the site include the Fairweather calorimeter house complete with the Gas Examiner's test room, and the work's officers. These are built to modern designs, are light, cheerfully decorated and comfortable.

Work is proceeding with the building of the Shell/W.-D. plant, which will contain four Shell combustors. The Woodall-Duckham Construction Co., Ltd., are the chief contractors and their sub-contractors, Air Products Ltd., will supply the necessary equipment for the production of tonnage oxygen.

YORKSHIRE JUNIORS PRESIDENT'S DAY

About 70 members of the Yorkshire Junior Gas Association accompanied Mr. R. E. White on his President's Day which included a visit to the gasworks at Tingley, near Leeds. Visitors at lunch included Mr. N. G. Appleyard, Leeds Group General Manager, Mr. C. S. Shapley, for many years the city's gas engineer; Mr. J. G. Tilley, Chairman of the Manchester District Section of the Institution of Gas Engineers, and Mr. J. G. Rutherford, President of the East of Scotland Junior Gas Association.

Londonderry profit

The Londonderry Gaslight Company showed a profit of £20,198, after taxation for the year ended December last. This figure is £2,940 less than the previous year. Revenue for the year showed an increase of £6,192 at £257,509, and expenditure was up by £11,764 at £230,209.

COKE MARKETING

A new divisional coke marketing department has been opened by the Central Division of the Scottish Gas Board in Perth. The division produces 130,000 tons of coke and up to 40,000 tons of breeze a year.

Reforming refinery gas

Continued from p. 126

cycle is approximately 50%, and the reforming portion, including purges approximately 50%.

Although this process has been successful in reforming natural gas and L.P. gas, unfortunately there are no figures available for its performance with refinery gases.

(b) Onia-Gegi process was originally developed on the Continent and employs a nickel catalyst. Recently the North Thames Gas Board installed four units at their Romford works to reform refinery gas from Shellhaven, the combined output from which is about 36 mill. cu.ft. per day.

Make and heating

During the 'make' phase refinery gas is admitted at the top of the steam preheater and mixes with superheated steam from steam admitted at the base. The mixture of steam and refinery gas passes downwards through the catalyst and leaves the set through a waste heat boiler and conventional type wash box. During the 'heating' phase air and heating medium are introduced together at the base of the steam preheater and burned in the combustion chamber, the waste gases from which passing in the same direction as for the 'make' phase leave the set through a waste heat boiler.

The refinery gas is reformed to a calorific value of about 350 B.t.u. per cu.ft. which is then raised as required by cold enrichment.

(c) The Segas process, entirely British in origin, and used for gasification of oils both here and overseas, has not so far been directly applied to the reforming of refinery oil gas.

No difficulty

Based on the successful reforming of butane and light distillate feedstocks at Sydenham and other considerations of the process, the reforming of refinery gas should not present any difficulty. The large Segas installation at the Isle of Grain has, therefore, been equipped for this duty.

During the 'make' period refinery gas is admitted to the top of the steam preheater meeting superheated steam which has passed upwards from the base of the steam superheater. The mixture of steam and refinery gas then passes downwards through the catalyst and leaves the set through the air preheater. During the heating phase air is admitted to the set at the top of the air preheater and flows in a reverse direction to the steam preheater and leaves through the waste heat boiler.

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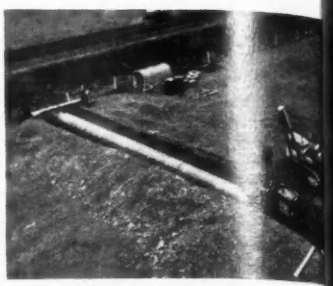

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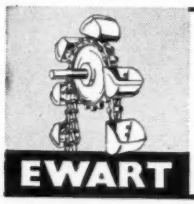

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